DETERMINATION OF THE EFFECTIVENESS OF DIFFERENT DOSES OF NEEM PRODUCTS AND TWO BIO-CONTROL AGENTS FOR COMBATING CHICKPEA POD BORER *Helicoverpa armigera* (Hubner)

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CERTIFICATE

This is to certify that thesis entitled, **"DETERMINATION OF THE EFFECTIVENESS OF DIFFERENT DOSES OF NEEM PRODUCTS AND BIO-CONTROL AGENTS FOR COMBATING CHICKPEA POD BORER *Helicoverpa armigera* (Hubner)"** 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 **SABBIR AHMED**, **Registration No. 08-03278** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2010
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ABSTRACT

A study was conducted at the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November, 2009 to March, 2010 to evaluate the effectiveness of different doses of neem products and bio-control agents on the basis of infestation level of chickpea pod borer (*Helicoverpa armigera)* on chickpea pods, variety BARI Chola-5. The experiment comprised of 7 treatments as T_1: Neem oil @ 3 ml/L of water at 7 days interval, T_2: Neem oil @ 5 m1/L of water at 7 days interval, T_3: Neem seed kernel @ 20 g/L of water at 7 interval, T_4: Neem seed kernel @ 30 g/L of water at 7 interval, T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval, T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water at 7 days interval and T_7: Untreated control.

The plants treated with T_2 treatment resulted significantly lowest pod infestation compared to those of other treatments during early, mid and late fruiting stage. Significantly the highest yield was also obtained from the treatment T_2. The treatments T_4 and T_1 also yielded more or less similar result as in treatment T_2. The yield contributing characters were found highest in T_2 treatment for longest plant, branches plant^{-1}, leaves plant^{-1}, pods plant^{-1}, pod length and number of seeds pod^{-1}. The highest BCR was found in the treatment T_2 may be due to the minimum infestation and cost compared to the other treatment components and the highest yield was produced in this treatment. The percentage of infestation of chickpea pod gradually increased from early fruiting stage to late fruiting stage by number and weight. Therefore, any control measure taken from pod initiation to harvest might be effective for controlling pod borer of chickpea.

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CHAPTER 1

INTRODUCTION

Chickpea (*Cicer arietinum* L.), commonly known as gram, is one of the important pulse crops in Bangladesh as well as in the world. It is an important leguminous grain in Asia, Africa and America. The crop is variously known as chola, boot or botjam in different parts of Bangladesh. In Bangladesh, about 85% of the gram is grown in greater districts of Faridpur, Jessore, Kustia, Rajshahi and Pabna. It is generally grown under rain-fed or residual soil moisture conditions in rabi season. Among the major pulses grown in Bangladesh, gram ranked fifth in area and production but second in consumption priority. It covers an area of 16,446 ha producing 12,315 tons of grain yields with national average of 761 kg ha^{-1} (BBS 2008).

Gram plays a vital role in human and animal nutrition having 20.8% protein (Gowda and Kaul 1982). It is a major source of dietary protein to the large vegetarian population of South Asian countries. Its dry stems and husks serve as good source of animal feeds (Kay 1979). Taking gram in “Iftar” during *Ramadan* is a common food in Bangladesh. Despite of an important source of human food and animal feed, it also helps in the management of soil fertility through symbiotic nitrogen fixation from the atmosphere, particularly in dry lands (Sharma and Jodha 1984; Suzuki and Konno 1982). According to the FAO (2006) yield of gram in Bangladesh is miserably low (761 kg ha^{-1}) as compared to that of other countries like India (833 kg ha^{-1}), Myanmar (1106 kg ha^{-1}), Mexico (1600 kg ha^{-1}), Israel

(1813 kg ha^{-1}), Russian Federation (2400 kg ha^{-1}), Kazakjhastan (3000 kg ha^{-1}) and China (6000 kg ha^{-1}). There are many factors responsible for low yield of gram such as drought, infertile soil, insect and diseases. Among them, insect pests appear to be the most vital factor. In Bangladesh, gram is attacked by eleven species of insect pests (Rahman *et al*. 1982). Among these pests the pod borer, *Helicoverpa armigera* (Hubner) is one of the most serious pests of the gram in different growing areas of Bangladesh (Begum *et al*. 1992).

In a countrywide survey, an average of 30 to 40% pod damage due to chickpea/gram pod borer was reported in Bangladesh. The young larvae of this pest feed on the foliage for some time and later bore into the pod. In favourable condition, the pod damage goes up to 90-95% (Shengal and Ujagir 1990; Sachan and Katti 1994).

Farmers are being reluctant to cultivate gram due to its susceptibility to pod borer. The young larva skeletonizes the leaves, while grown up larva bores the pods and feeds on the seeds, thereby rendering them unfit for human consumption.

At present, effective control techniques other than insecticide application against the pest are not available. The poor farmers of Bangladesh cannot always afford to use insecticides. Again, indiscriminate use of insecticides for the management of insect pests has resulted in the development of resistance to insecticides, pest resurgence and appearance of secondary pests (Shengal and Ujagir 1990; Butter *et al*. 1992). Moreover, continuous use of insecticides leads to the hazardous effects

on the pollinators, natural enemies like predators, parasitoids, parasites etc. and also causes the environmental pollution (Nugrar and More 1998).

Under these circumstances, it becomes necessary to findout some eco-friendly alternative methods for pod borer management. The manipulation of the cultural practices like changing the dates of sowing, using various levels of different fertilizers, intercropping chickpea with different companion crops, screening of genotypes resistant to pod borer and using botanical and bioagents can be ecofriendly components in formulating the integrated pest management approach. In Bangladesh sufficient information on chickpea pod borer for its proper management is not available so far and no in-depth studies have been made. The chemical insecticides still remain the key tools for the management of the pest.

Under the above perspective, bio-control agents and botanicals has been thought to be an environment friendly option for the management of insect pests in gram. Therefore, present study was planned and designed with the following objectives:

1. To know the infestation status of pod borer in chickpea.
2. To evaluate the effect of different doses of neem products and two bio-control agents against chickpea pod borer.
3. To find out an effective suitable control option for suppressing the chickpea pod borer.

CHAPTER 2

REVIEW OF LITERATURE

The pod borer, *Helicoverpa armigera* (Hubner) is a main and serious pest of gram in Bangladesh and elsewhere in the world. For better understanding efforts have been made to review the available literature related to this pest distribution, pest status and host range, and its biology is necessary. Another way a number of studies on botanicals or bio-control with pest management of chickpea have been done and reported elsewhere in the world. However, studies in this area appeared very limited in Bangladesh. For a better understanding and to know the research status on botanicals or bio-control on pod borer management of chickpea, the relevant available literature on this crop and others have been reviewed and presented below:

2.1 Distribution of pod borer

Pod borer is a polyphagous pest, which spreads in wide geographical areas and it extends from Cape Verde Islands in the Atlantic, through Africa, Asia and Autralasia, to the South Pacific Islands and from Germany in the north to New Zealand in the south (Hardwick 1965). Rao (1974) stated that in India, *H. armigera* is distributed over a wide range and caused serious losses to many crops, including chickpea, particularly in the semi-arid tropics. Ibrahim (1980) observed that *Heliothis* spp. is of considerable economic importance as pests on many Egyptian crops but *H. armigera* is the most abundant species throughout Egypt. Zalucki *et al.* (1986) reported that *H. armigera* was one of the

widest distributions of any agricultural pests, occurring throughout Asia, Australia, New Zealand, Africa, southern Europe and many Pacific islands.

2.2 Pest status and host range of pod borer

Jayaraj (1962) reported that *Heliothis* could breed on a wide range of plants. The crops attacked in many countries were maize, sorghum, oats, barley, pearl millet, chickpea, pigeonpea, cowpea, peas, various beans, cotton, sunflower, safflower, tobacco, tomato, brinjal, cucurbits, sweet potato, groundnut, flax, citrus, sunhemp, potato etc. Bhatnagar and Davies (1978) reported that 50 species of crop plants and 48 species of wild and weed species of plants found for attacking by *H. armigera* at Patancheru, Andhra Pradesh, India, whereas 96 crops and 61 weeds and wild species have been recorded elsewhere in India. The most important carryover weed hosts in the hot summer season are *Datura metel, Acanthospernium hispidum* and *Gynandropsis gynandra* for *H. armigera, H. assulta* and *H. pelligera.*

Reed and Pawar (1982) observed that *H. armigera* was the dominant and primary pest of cotton, maize and tomatoes in some countries of Africa, Europe, America, Australia and Asia. In India, it was a dominant pest on cotton in some areas and in most of the areas, on several other crops particularly pigeon pea and chickpea. On both the major pulse crops, *H. armigera* commonly destroyed more than 50% of the yield. Garg (1987) studied the host range of *H. armigera* in the Kumaon Hills, India and found that the larvae of *H. armigera* infested different plant parts of variety of crops like wheat, barley, maize, chickpea, pea,

tomato, pigeon pea, lentil, onion and okra. He also pointed out that chickpea appeared to be the most susceptible crop followed by pigeon pea, tomato and pea. In addition, it was also observed on some wild grasses and ornamental plants such as roses and chrysanthemums.

Fitt (1991) cited from an experiment conducted in the south Asian region that *H. armigera* was a serious pest of cotton, chickpea, pigeon pea, groundnut, cowpea, *Vigna* species, okra, tomato, castor, sunflower, maize, sorghum and many other crops.

2.3 Biology of *H. armigera*

2.3.1 Host preference for oviposition

Parsons *et al.* (1937) reported that chickpea was most attractive for oviposition of pod borer, while Reddy (1973) and Loganathan (1981) reported that pigeon pea was the most preferred host for oviposition.

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

(a) (b)

Plate 1. Photographs showing (a) pod borer larva inside the pod (b) pod borer lavae

2.3.2 Mating and oviposition

The eggs were laid singly, late in the evening, mostly after 2100 hr to midnight. On many host plants, the eggs were laid on the lower surface of the leaves, along the midrib. Eggs were also laid on buds, flowers and in between the calyx and fruit (Continho, 1965).

Roome (1975) studied the mating behaviour of *H. armlgera* and reported that from 02.00 to 04.00 hr the males flew above the crop while the females were stationary and released a pheromone. During this period males were highly active and assembled around females.

Singh and Singh (1975) found that the pre-oviposition period ranged from 1 to 4 days, oviposition period 2 to 5 days and post-oviposition period 1 to 2 days However, maximum numbers of egg were laid between 2100 and 2300 hours. The moths did not oviposit during the daytime. Loganathan (1981) observed peak mating activity at 04.00 hr.

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

Tayaraj (1982) reported that oviposition usually started in early June, with the on set of pre-monsoon showers, adults possibly emerging from diapausing pupae and also from larvae that had been carried over in low numbers on crops and weeds

during the summer. Reproductive moths were recorded throughout the year ovipositing on the host crops and weeds with flowers. The pest multiplied on weeds, early-sown corn, sorghum, mungbean and groundnut before infesting pigeon pea in October-November and chickpea in November-March.

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

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

2.3.3 Egg

The eggs of *H. armigera* are nearly spherical, with a flattened base, giving a somewhat dome-shaped appearance, the apical area surrounding the micropyles smooth, the rest of the surface sculptured in the form of longitudinal ribs. The freshly laid eggs are 0.4 to 0.55 mm in diameter, yellow-white, glistening and changing to dark brown before hatching .The incubation period of the eggs is longer in cold weather and shorter in hot weather, being 2 to 8 days in South Africa and 2.5 to 17 days in the United States and 2 to 5 days in India (Srivastava and Saxena 1958; Singh and Singh 1975).

2.3.4 Larva

The newly hatched larva is translucent and yellowish white in, with faint yellowish orange longitudinal lines. The head is reddish brown, thoracic and anal shields and legs are brown and the setae are dark brown. The full-grown larva is about 35 to 42 mm long; general body color is pale green with one broken stripe along each side of the body and a distal line is present. White short hairs are scattered all over the body. Prothorax is slightly more brownish than meso and metathorax. Crochets are arranged in biordinal symmetry on the prolegs. The underside of the larva is uniformly pale. The general color is extremely variable; and the pattern may be in shades of green, straw yellow and pinkish to reddish brown or even black (Neunzig 1964; Singh and Singh 1975).

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

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

2.3.5 Pupa

The pupa is 14 to 18 mm long, mahogany-brown, smooth-surfaced and rounded both anteriorly and posteriorly, with two tapering parallel spines at the posterior tip (Singh

and Singh 1975). The pupa of *H. armigera* undergoes a facultative diapause. The non-diapause pupal period for *H. armigera* was recorded as 14 to 40 days in the Sudan Gezira, 14 to 57 days in Southern Rhodesia, 14 to 37 days in Uganda and 5 to 8 days in India (Jayaraj 1982). According to Bhatt and Patel (2001) the pupal period ranged from 14 to 20 days in Gujarat, India.

2.3.6 Adult

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

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

2.3.7 Generations

Hsu *et al*. (1960) observed three generations of *H. armigera* each year in China while Reed (1965) reported that the pest completed four generations from

September to March under western Tanganyika conditions. Singh and Singh (1975) reported that *H. armigera* passed through four generations in the Punjab, India; one on chickpea during March; two on tomato, from the end of March to May; and one on maize and tomato in July-August. Bhatnagar (1980) observed that seven to eight generations of *H. armigera* were present each year in Andhra Pradesh, India.

2.4 Biological control

2.4.1 *Trichogramma Sp.*

Trichogramma are extremely tiny wasps in the family Trichogrammatidae. While it is uncommon for an insect's scientific name, especially one so long and unusual as *Trichogramma*, to also become its common name, the commercial development of this natural enemy and the fact that it attacks so many important caterpillar pests has earned it a place in the popular vocabulary of many pest management advisors and producers.

Trichogramma wasps occur naturally in almost every terrestrial habitat, and some aquatic habitats as well. They parasitize insect eggs, especially eggs of moths and butterflies. Some of the most important caterpillar pests of field crops, forests, and fruit and nut trees are attacked by *Trichogramma* wasps. However, in most crop production systems, the number of caterpillar eggs destroyed by native populations of *Trichogramma* is not sufficient to prevent the pest from reaching damaging levels.

Recognizing the potential of *Trichogramma* species as biological control agents, entomologists in the early 1900s began to mass rear *Trichogramma* for insect control. Although a small commercial production of *Trichogramma* eventually developed in the U.S., insect control research and commercial efforts focused on the development of chemical pesticides following the discovery of DDT. This was not the case in the Soviet Union and China, both of which developed programs to control several crop pests with *Trichogramma*. In these countries, insectaries were less expensive and less sophisticated than production facilities for synthetic insecticides, and could be located on farms where labor was inexpensive and readily available. Also, control standards were not as stringent, and releasing *Trichogramma* was often better than no control at all (King 1993).

Species and distribution

The genus *Trichogramma* is one of 80 genera in the family *Trichogrammatidae*. All members of this family are parasites of insect eggs. *Trichogrammatidae* includes the smallest insects, ranging in size from 0.2 to 1.5 mm. Within the genus *Trichogramma,* there are 145 described species worldwide; 30 species have been identified from North America and an estimated 20 to 30 species remain to be described. The most commonly species abundance in crops and orchards are *atopovirilia, brevicapillum, deion, exiguum, fuentesi, minutum, nubilale, platneri, pretiosum,* and *thalense* (O'Neil *et al*. 1998).

Life cycle

The effect of temporary host deprivation on parasitization rates of *T. cacoeciae* [*T. cacaeciae*] and *T. dendrolimi* was investigated by Thakur *et al.* (2000). The insect host in the experiments was *Sitotroga cerealella*. The study was conducted with females that allowed to engage in 3 days of oviposition after various periods of host deprivation. It seems that the production and management of eggs by the two species is completely different. During the first day of oviposition, parasitization by *T. cacoeciae* was almost unaffected after 1 to 5 days of host deprivation. As deprivation time increased, however, the number of parasitized hosts decreased from an average of 28.6±2.0 hosts provided at emergence to an average of 12.5±2.3 hosts when the waiting time was 10 days. The number of hosts parasitized on the first day of parasitization by *T. dendrolimi* was not affected whatever the waiting tests period. During the second or third days of oviposition, the lack of suitable hosts for *T. cacoeciae* did not depress egg-laying potentiality, whereas a strong reduction in parasitization rates by *T. dendrolimi* occurred in the next 2 days of oviposition whatever was the waiting period. This leads to ca. 50% reduction in total activity of 3 days of oviposition. The data suggest that *T. dendrolimi* is a typical proovigenic species, while *T. cacoeciae* is neither definitely proovigenic nor synovigenic. A slight decrease in rate of emergence of offspring of *T. cacoeciae* females that had waited 8 to 10 days for their hosts was observed.

The functional response of third generation of the *Trichogramma brassicae* reared in laboratory, was studied by Ahmad and Chandel (2004) at various densities (5,

10, 20, 40, 80, 100, 120) of the *Sitotroga cerealella* eggs under 25+or-1 degrees C, %60±-5 RH, and 16 L:8 D.h. photoperiod. One day old eggs of Angoumois grain moth. *S. cerealella*, in 15 replications for 24 hours were exposed to one-day old female wasps. Functional response of *T. brassicae* was found to be type III. Searching efficiency (a) handling time and maximum attack rate were estimated, 0.168±0.055, 1.468±0.121 and 16.34, respectively.

2.4.2 *Bacillus thuringiensis*

Bacillus thuringiensis Berliner (or Bt) is a Gram-positive, soil-dwelling bacterium, commonly used as a biological alternative to a pesticide; alternatively, the Cry toxin may be extracted and used as a pesticide. *B. thuringiensis* also occurs naturally in the gut of caterpillars of various types of moths and butterflies, as well as on the dark surface of plants.

Bacillus thuringiensis isolates were detected by Theunis *et al*. (1998) in 57% of 801 samples of rice grain dust, soil, rice field arthropods, and miscellaneous habitats (rice straw compost and mammal faeces) collected from 100 sites in the Philippines. The collection yielded 3950 isolates of *B. thuringiensis* (8.7 isolates/ positive sample). Grain dust from rice mills was the richest source (63%) of the samples were positive, with 10.2 isolates/positive sample, followed by rice field arthropods, soil, and miscellaneous habitats. Subsamples of isolates representing the diversity of isolate sources and o-endotoxin profiles were bioassayed against the yellow stem borer, *Scirpophaga incertulas* and striped stem borer, *Chilo suppressalis*.

Anjali and Nidhi (2006) conducted a field study in Rajasthan, India, during 2002-

04 to evaluate cypermethrin, carbaryl, endosulfan, malathion, triazophos, *Bacillus thuringiensis* (Bt) and Bt+carbaryl for the control of aubergine shoot and fruit borer (*Leucinodes orbonalis*). The results revealed that cypermethrin (0.007%) and carbaryl (0.02%) were at par with each other and were significantly superior to all other treatments in terms of percent shoot damaged, fruit damage on number and weight basis and on yield basis.

Nadaf *et al.* (2006) carried out a field experiment to study the effect of sequential applications of *Helicoverpa armigera* nuclear polyhedrosis virus (HaNPV) at 250 LE/ha, *Bacillus thuringiensis* subsp. kurstaki (Btk; Dipel) at 2 ml/l, Nimbecidine (5%) and carbaryl 50 WP on *H. armigera* on chilli (*Capsicum annuum cv.* Byadagi) in Dharwad, Karnataka, India, during kharif 2001. Btk-HaNPV-Btk recorded significantly the lowest larval population (1.3 larvae per plant) after the first, second and third sprays. The main fruit damage was lowest (9.21%) and the yield of green chilli was significantly highest (14.34 q/ha) in Btk-HaNPV-Btk, with benefit: cost ratio of 1:93.

Nadaf and Kulkarni (2005) conducted five management modules for the control of the fruit borer, *Helicoverpa armigera*, on chilli (*Capsicum annuum*), comprising three sprays of *Bacillus thuringiensis* var. kurstaki (Btk; Dipel 8L; 2 ml/ha), *H. armigera* nuclear polyhedrosis virus (HaNPV at 250 LE/ha), neem (Nimbecidine 1500 ppm azadirachtin; 5%) and carbaryl (Sevin 50 WP; 4 g/litre) were evaluated in different combinations and compared with the standard recommendation of two sprays of carbaryl at the above concentration, 7 and 11 weeks after transplanting and an untreated control. The experiment was conducted

during the 2001 kharif season in Dharwad, Karnataka, India. The data on mean larval population at the initiation of spray programme and at 3 and 7 days after each spray, revealed that the larval count was consistently lower in Module-2 (M< sub>2</ sub>), comprising Btk spray followed by HaNPV and Btk sprays at 15-day interval. A similar trend was evident with respect to fruit damage by the borer in different modules, i.e. the fruit damage was minimum in M< sub>2</ sub> (9.12%) as against 10.01 to 13.68% in other modules, as against 24.87% in control. Thus, there was 23.95 to 54.40% increase in green fruit yield in different modules over the control. However, due to the overall poor yield in all the treatments including untreated control, the cost-benefit (C:B) analysis showed poor C:B ratios varying between 1:1.49 and 1:1.93 among different modules.

Puranik *et al.* (2002) evaluated on different *B. thuringiensis* formulations in comparison with neem and chemical insecticides against aubergine (cv. Manjari Gota) shoot and fruit borer, *L. orbonalis* in Pune, Maharashtra, India, during the kharif season of 1999-2000 indicated that five sprays of Dipel *B. thuringiensis* subsp. kurstaki 8L at 0.2 per cent at 10 day intervals which resulted in minimum shoot (9.56%) as well as fruit (11.78%) infestation and maximum yield of marketable fruits (196.96 q/ha) and proved to be the most effective treatment. It was however, at par with Delfin *B. thuringiensis* subsp. kurstaki WG, Halt cypermethrin WP, and Biolep *B. thuringiensis* subsp. *kurstaki* WP, all at 0.2 per cent concentrations. This was followed by Biobit *B. thuringiensis* subsp. *kurstaki* HPWP, Spicturin, and chemical insecticides cypermethrin and endosulfan, while neem was the least effective treatment.

2.5 Neem products

Field studies were conducted by Korat and Dabhi (2009) during three successive wet seasons (1995-97) in rice fields in Gujarat, India, to determine the efficacy of various concentrations of azadirachtin (Nimbicidine, Neemax, and Neem Gold (all 300 ppm), Econeem (3000 ppm), Neem Azal T/S (10 000 ppm) and Fortune Aza (1500 ppm)) compared to chlorpyrifos for the control of *Cnaphalocrocis medinalis, Sogatella furcifera* and *Scirpophaga incertulas*. Results showed that although all neem formulations were effective against pests and resulted in an increased yield none were superior in efficacy to chlorpyrifos.

Safe clean, safe max, and neem oil are the botanicals products use for controlling insect and pests. Safe clean is a detergent type products and safe max produced from mehogoni plant oil, whereas neem oil prepared from leaf of neem plant.

Butani and Mittal (1993) studied the efficacy of neem seed kernel suspension and several conventional insecticides against *H. armigera* on chickpea and reported that all the tested insecticides significantly reduced the pest population and neem seed kernel suspension being equally effective.

Sarode *et al*. (1994) studied the efficacy of different doses of neem seed kernel extract (NSKE) for the management of pod borer in chickpea. It was found two sprays of NSKE 6% at 7 days interval provided significantly high larval reduction (69.45%) followed by two sprays of NSKE 5% (67.28%) and suggested that it may be used in managing *H. armigera* on chickpea.

Jeyakumar and Gupta (1999) reported neem seed kernel extract (NSKE) reduced the oviposition of *H. armigera* in a dose dependent manner during the exposure periods of 0-24 h and 24-48 h and showed oviposition deterrency effect. Reduction of oviposition was highest (60.9%) with 10% NSKE. The hatchability of the laid eggs was also affected on NSKE treated surface.

Bajpai and Sehgal (2000) compared endosulfan with seven botanical insecticides, including neem, karanj (*Pongamia pinnata*) and tobacco formulations for control of pod borer on chickpea at Pantnagar, India. Neem gave the highest pod borer control (40.2% pod damage) and yields. Of the botanicals, pod damage at maturity was lowest with karanj oil followed by the neem product Green Mark or nicotine sulfate and yield was highest with karanj oil.

Visalakshimi *et al*. (2005) reported that application of neem effectively reduced the oviposition of *H. armigera* through out the crop period. Among various IPM components (neem 0.06%, HaNPV 250 L/ha, bird perches one/plot, endosulfan 0.07%), neem and HaNPV found as effective as endosulfan in the terms of reduction larval population and pod damage, further, endosulfan comparatively found toxic to natural enemies present in chickpea eco-system.

Sasikala *et al.* (1999) studied during rabi 1998-99 at the Agricultural College Farm, Bapatla for the management of the brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee, involving eco-friendly methods. The treatments included 5% neem seed kernel extract (NSKE), neem oil (0.2%), *Bacillus thuringiensis* var. (B.t.) *kurstaki* (0.15%), lufenuron (0.02%), carbaryl (0.15%), their combinations

(except NSKE), mechanical removal and destruction of infested shoots and fruits with larvae, and release of egg parasitoid, *Trichogramma japonicum* Ashm. Treatment by mechanical destruction of infested shoots and fruits with larvae, neem oil (0.2%) and release of the egg parasitoid, *T. japonicum* resulted in very good control of shoot and fruit borer as compared to control. The respective percentage of shoot infestation and fruit damage (on number basis) in these treatments were 14.46, 20.24; 21.06, 23.35; and 23.36 & 28.00 vis-a-vis 52.60 & 52.55 per cent in control plots. Plots treated with neem oil (0.2%), neem oil (0.1%) + B.t. (0.075%), neem oil (0.1%) + lufenuron (0.01%), and neem oil (0.1%) + carbaryl (0.075%) gave higher fruit yield (40.76, 33.80, 31.35 and 29.07 kg/plot, respectively, compared with 17.5 kg/plot obtained from control plots.

Hossian (2007) observed the efficacy of some synthetic and biopesticides against pod borer, *H. armigera* damage in chickpea was studied at the Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh during rabi cropping season of 2004-05. Synthetic and biopesticides reduced pod borer damage significantly. Significantly lowest pod damage was observed in cypermethrin (5.75%) and HNPV (5.86%) sprayed plots followed by carbaryl (6.05%) and dimethoate (7.92%) treated plots. The bio-control agent, HNPV, showed equally the best performance like synthetic insecticides and also showed higher efficacy than neem based insecticides like nimbicidine (azadirachtin 0.03% EC). Pod damage reduction by synthetic insecticides and bio-pesticides over untreated control ranged from 24.98 to 64.08%. It ranged from 50.53 to 64.08% in synthetic insecticides and 24.98 to 63.40% in bio-pesticides. Significantly the highest yield

(1856 kg/ha) obtained from HNPV sprayed plots which was statistically identical to cyperme-thrin followed by azadirachtin 0.03% EC. The highest net income ($ 105/ha) and marginal benefit cost ratio (3.35) was recorded from HNPV spray followed by cypermethrin ($ 87/ha). Hence, it might be concluded that HNPV is the best tool in managing pod borer in chickpea considering efficacy, profitability and safe environment.

Bhat *et al.* (1988) reported that neem seed extract was the next best treatment to monocrotophos against the pod borers, *M. testulalis* and *C. ptychora* on cowpea. Kareem *et al.* (1988b) evaluated the efficacy of neem seed bitter (NSB) @ 5000 ppm and NSKE 3 per cent against pod borers (*Etiella* sp., *Maruca* sp. and *Helicoverpa* sp.) in mung bean. The per cent pod damage was significantly reduced by NSB (22%), NSKE (20%) and monocrotophos (16%) as against untreated control (34%).

Ramasubramanian and Babu (1991) reported that neem seed extract and neem oil were on par with each other and were more effective than carbaryl in controlling the spotted pod borer, *Maruca testulalis* in lablab bean.

Jackai and Oyediran (1991) observed that neem oil emulsifiable concentrate (NOEC) at 5, 10 and 20 per cent concentrations exhibited a high degree of insecticidal activity to 3rd instar larvae of pod borer, *M. testulalis* in cowpea.

Bottenberg and Singh (1996) found that, on an average, aqueous neem leaf extracts at 5 and 10 per cent concentrations reduced the *M. testulalis* pod damage

by 12 per cent in cowpea cv. 715 and by 16 per cent in cultivar 941 compared to untreated control.

Balikai *et al.* (1997) reported the lowest pod damage (39.8%) and highest seed yield (10.2q/ha) from the plots receiving three sequential sprays of NPV 250 LE/ha, cypermethrin 0.1 per cent and NSKE 5 per cent at 15 days interval starting from 50 per cent flowering on redgram, against *H. armigera.*

Akhauri and Yadav (1999) observed that aqueous extracts of neem seed kernel and green castor leaves each at 5 and 10 per cent concentration, neem and mahua oils and mangraila (*Nigella sativa* L.*)* seed extract in water each at 2 per cent concentration, were effective in controlling *Melanagromyza obtusa*, *Apion clavipes* and *H. armigera* in pigeonpea.

Chickpea plots treated with leaf extracts of *Nicotiana tobacum* L. 5 per cent, seed extract of *Pongamia glabra* (Vent) 5 per cent, indiara (a neem based herbal product) 1 per cent and NSKE 5 per cent, exhibited lower population build up of *H. armigera* (Kulat *et al*. 2001).

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November, 2009 to March, 2010 to evaluate the effectiveness of different doses of neem products and bio-control agents for combating pod borer, *Helicoverpa armigera* of chickpea. A brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection and analysis of different parameters under the following headings has been given.

3.1 Location

The experiment was carried out in the field of Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74^/$N latitude and $90^0 35^/$E longitude and an elevation of 8.2 m from sea level (Anonymous 1989).

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon . The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and presented in Appendix I.

3.3 Weather condition of the experimental site

The climatic condition of experimental site is under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*. 1979). Details of the meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix II.

3.4 Planting material

The seeds of BARI Chola-5 were used for the study. This variety was developed by Bangladesh Agricultural Research Institute (BARI) and exposed for cultivation in the year of 1996 (BARI 2006) through the selection process among the different germplasms that generally has been cultivated in different areas of Bangladesh. It is a spreading type plant and can be easily grown in minimum or shading light.

3.5 Land preparation

The experimental field was first opened on November 15, 2009 with the help of a power tiller and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a desirable fine tilth. The visible larger clods were hammered to break into small pieces. All kinds of weeds and residues of previous crop were removed from the field. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.6 Fertilizer application

Standard doses of fertilizers comprising N, P and K @ 40 kg, 25 kg and 25 kg per hectare in the form of Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP), respectively were applied during land preparation. The whole amount of TSP and MP were applied as basal dose at the time of seed sowing. Total Urea was broadcasting maintaining two times during seedlings and vegetative stage.

3.7 Seed processing and treatment

The seeds were treated with Vitavax 200 @ 2 g per kg seed to prevent the damage of seedlings against foot and root rot disease.

3.8 Sowing of seeds

The seeds were sown in each plot on 23 November 2009 in rows with spacing of 40 cm × 30 cm.

3.9 Treatments

Seven treatments were considered for this treatment as follows:

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed karnel @ 20 g/L of water at 7 interval

T_4: Neem seed karnel @ 30 g/L of water at 7 interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water at 7 days interval

T_7: Untreated control

3.10 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The treatments were randomly allotted in each block. The unit plot size was 3m × 2m with a distance of 50 cm between the plots and 100 cm between the replications.

3.11 Intercultural operations

Irrigation was applied for avoiding moisture stress and ensuring good germination. Intercultural operations like thinning, weeding and mulching were done as and when necessary for proper growth and development of the crop.

3.12 Monitoring and data collection

The growth and development of the chickpea plant were closely examined at regular intervals commencing from germination to harvest. The following data were collected during conducting the study.

The parameters were considered during data collection as follows:

- Number of healthy pods
- Number of infested pods
- Fruit infestation in number (%)
- Weight of Healthy pods
- Weight of Infested pods
- pods infestation in weight (%)

- Plant height at harvest
- Number of branches plant^{-1}
- Number of leaves plant^{-1}
- Number of pods plant^{-1}
- Pod length
- Number of seeds pod^{-1}
- Weight of 1000 seeds (g)
- Yield per hectare (ton)

3.13 Determination of pod borer infestation plant^{-1}

Pod borer infestation plant^{-1} was recorded at 7 days intervals from the randomly tagged 10 plants in central rows initiating from flowering to pod maturity. The entire period was divided into early, mid and late pod maturing stage and percentage of pod damage due to pod borer was calculated from the pods of 10 randomly selected plants from the central rows by number and weight basis. Early, mid and late pod maturing stage composed of 3, 5 and 4 harvest respectively during the data collection period.

3.14 Determination of pod borer damage by number

All the pods were counted from 10 randomly selected plants from middle rows of each plot and examined. The damaged (bored) and total numbers of pods were counted and the percent pod damage was calculated using the following formula:

$$\% \text{ Pod damage} = \frac{\text{Number of damaged pod}}{\text{Total number of pod}} \times 100$$

3.15 Determination of pod borer damage in weight

All the pods were counted from 10 randomly selected plants from middle rows of each plot and examined. The damaged (bored) and total numbers of pods were weighted the percent pod damage was calculated using the following formula:

$$\% \text{ Pod damage} = \frac{\text{Weight of damaged pod}}{\text{Total weight of pod}} \times 100$$

3.16 Harvest and post harvest operations

The plants of middle three rows, avoiding border rows, of each plot were harvested. The pods were then threshed; cleaned and dried in bright sunshine. The yield obtained from each plot was converted into yield per hectare.

3.17 Procedure of data collection

3.17.1 Plant height at harvest

The plant heights of 10 randomly selected plants were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in centimeter (cm). Data were recorded from the inner rows plant of each plot during harvesting period.

3.17.2 Number of branches plant^{-1}

The branches were counted from selected plants. The average number of branches plant^{-1} was determined. Data were recorded as average from 10 randomly selected plants considering the inner rows of each plot at final harvest.

3.17.3 Number of leaves plant^{-1}

The leaves (trifoliate) were counted from selected plants. The average number of leaves plant^{-1} was determined. Data were recorded as average from 10 randomly selected plants considering the inner rows of each plot starting at final harvest.

3.17.4 Number of pods plant^{-1}

Number of total pods of selected plants from each plot was counted and the mean number was expressed on plant^{-1} basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.17.5 Pod length

Pod length of selected plants from each plot was counted and the mean length was expressed on pod^{-1} basis. Data were recorded as the average of 10 pods selected at random from the inner rows plant of each plot.

3.17.6 Number of seeds pod^{-1}

The number of seeds in each pod was also recorded from randomly selected pods at the harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.17.7 Weight of 1000-seed (g)

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g). Data were recorded as the average of 10 plants selected at random from the inner rows.

3.17.8 Seed yield (kg/plot)

Total harvest seed from a unit plot was collected cleaned, dried and weighed by using a digital electric balance and weight was expressed in kilogram (kg).

3.17.9 Seed yield (t ha^{-1})

The seeds collected from 6.0 m^2 of each plot were sun dried properly. The weight of seeds was taken and converted into the yield t ha^{-1}.

3.18 Statistical analysis

The data obtained for different characters are statistically analyzed to find out the significance of the difference among the treatments. The mean values of all the characters are evaluated and analysis of variance is done by the 'F' (variance ratio) test. The mean differences are evaluated by Duncan's Multiple Range Test (DMRT) at 0.05 level of probability (Gomez and Gomez 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of different doses of neem products and bio-control agents against chickpea pod borer. The analysis of variance (ANOVA) of the data on pod infestation, different yield contributing characters and yield are given in Appendix III-X. The results have been presented by using different Tables & Graphs and discussed with possible interpretations under the following headings and sub headings:

4.1 Pod bearing status at early fruiting stage

4.1.1 Chickpea pod by number

Number of healthy pods, infested pods and percent infestation of chickpea at early fruiting stage for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Table 1). The highest number of healthy pods plant^{-1} (28.90) was recorded in T_2 (neem oil 5 ml/L of water at 7 days interval) which was statistically similar (27.30 and 26.10) with T_4 (neem

seed kernel @ 30 g/L of water at 7 days interval) and T_1 (neem oil 3 ml/L of water at 7 days interval), respectively. It was followed (23.70) by T_5 (*Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval). On the other hand, the lowest number (20.50) was recorded in T_7 (untreated control) which was statistically similar (20.70 and 22.10) with T_3 (neem seed kernel @ 20 g/L of water at 7 days interval) and T_6 (*Bacillus thuringiensis* serovar *kurstaki* 1.5 ml/L of water at 7 days interval), respectively. The highest number of infested pods $plant^{-1}$ (2.80) was recorded in T_7, whereas the lowest number (0.63) was recorded in T_2 which was statistically identical (0.83) with T_4 and followed (1.17, 1.33 and 1.40) by T_1, T_6, T_3 and T_5, respectively (Table 1).

The highest percent of infested pods $plant^{-1}$ by number (12.04%) was recorded in T_7 which was followed (6.33% and 5.58%) by T_3, T_5 and T_6, respectively. Again, the lowest percent by number (2.16%) was recorded in T_2 which was statistically similar (3.02%) with T_4 and closely followed (4.28) by T_1. Pod infestation percentage reduced over control at early fruiting stage and the highest value (82.06%) was recorded from the treatment T_2 and the lowest value (47.43%) from T_3. From this findings it is revealed that spraying of neem oil @ 5 ml/L of water at 7 days interval yielded maximum healthy pods and minimum infested pods, the lowest percent of pod infestation followed by neem seed kernel @ 30 g/L of water at 7 days interval, while in untreated control treatment gave the minimum healthy pods, maximum infested pods and highest percentage of infestation under the trail followed by neem seed karnel @ 20 g/L of water at 7 days interval (Table 1). Sarode *et al*. (1994) reported earlier that two sprays of NSKE 6% at 7 days

interval provided significantly high larval reduction (69.45%) followed by two sprays of NSKE 5% (67.28%) and suggested that it may be used in managing *H. armigera* on chickpea. Similar results also reported by Jeyakumar and Gupta (1999), Bajpai and Sehgal (2000) and Visalakshimi *et al*. (2005).

Table 1. Effect of different doses of neem products and bio-control agents against chickpea pod borer by number at early fruiting stage during the period from November, 2009 to March, 2010

Treatment	Chickpea pod by number			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
T_1	26.10 ab	1.17 b	4.28 c	64.45
T_2	28.90 a	0.63 c	2.16 d	82.06
T_3	20.70 c	1.40 b	6.33 b	47.43
T_4	27.30 a	0.83 c	3.02 d	74.92
T_5	23.70 bc	1.40 b	5.58 b	53.65
T_6	22.10 c	1.33 b	5.69 b	52.74
T_7	20.50 c	2.80 a	12.04 a	--
$LSD_{(0.05)}$	3.431	0.239	1.179	--
CV(%)	7.97	9.71	11.87	--

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

4.1.2 Chickpea pod by weight (g)

Weight of healthy pods, infested pods and percent infestation of chickpea at early fruiting stage for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Table 2). The highest weight of healthy pods plant^{-1} (173.82 g) was recorded in T_2 which was statistically similar with T_4 (163.08 g) and T_1 (152.05 g) respectively and closely followed by T_5 (136.04 g) while, the lowest weight in T_7 (103.31 g) treatment which was statistically similar with T_3 (111.49 g) and T_6 (122.92 g) respectively. The highest weight of infested pods per plant was recorded from T_7 (14.63 g) which was followed by T_5 (8.17 g) on the contrary, the lowest weight was recorded from T_2 (5.30 g) which was statistically similar with T_4 (6.12 g), T_1 (6.61 g), T_3 (7.23 g) and T_6 (7.90 g) respectively (Table 2).

The highest percent of infested pods plant^{-1} by weight was recorded from T_7 (12.41%), while the lowest percent by weight was recorded in T_2 (2.92%) which was statistically similar with T_4 (3.58%) and T_1 (4.14%), and followed by T_5 (5.72%), T_6 (6.06%) and T_3 (6.08%) respectively. Pod infestation percentage reduced over control at early fruiting stage the highest percent of reduction over control was recorded for the treatment T_2 (76.47%) and the lowest percent from T_3 (51.01%) (Table 2). Pod infestation is higher in most treatment on weight basis over number basis at early fruiting stage under the present trial (Figure 1). Sarode *et al*. (1994) reported earlier that two sprays of neem seed kernel extract (NSKE) 6% at 7 days interval provided high larval reduction (69.45%) followed by two sprays of NSKE 5% (67.28%).

Table 2. Effect of different doses of neem products and bio-control agents against chickpea pod borer by weight at early fruiting stage during the period from November, 2009 to March, 2010

Treatment	Chickpea pod by weight (g)			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
T_1	152.05 ab	6.61 bc	4.14 c	66.64
T_2	173.82 a	5.30 c	2.92 c	76.47
T_3	111.49 d	7.23 bc	6.08 b	51.01
T_4	163.08 a	6.12 bc	3.58 c	71.15
T_5	136.04 bc	8.17 b	5.72 b	53.91
T_6	122.92 cd	7.90 bc	6.06 b	51.17
T_7	103.31 d	14.63 a	12.41 a	--
$LSD_{(0.05)}$	22.65	2.575	1.505	--
CV(%)	9.26	18.10	14.47	--

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

4.2 Pod bearing status at mid fruiting stage

4.2.1 Chickpea pod by number

Number of healthy, infested and percent infestation of chickpea pods at mid fruiting stage for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Table 3). The highest number of healthy pods plant^{-1} (44.10) was recorded in T_2 (neem oil 5 ml/L of water at 7 days interval) treatment which was statistically similar (39.83 and 38.90) with T_4 (neem seed karnel @ 30 g/L of water at 7 days interval) and T_1 (neem oil 3 ml/L of water at 7 days interval), respectively and it was closely followed (37.13) by T_5 (*Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval), on the contrary, the lowest number (26.50) was recorded in T_7 (untreated control) which was statistically similar (28.80 and 29.07) with T_3 (neem seed karnel @ 20 g/L of water at 7 days interval) and T_6 (*Bacillus thuringiensis* serovar *kurstaki* 1.5 ml/L of water at 7 days interval), respectively. The highest number of infested pods per plant was recorded from T_7 (4.20), whereas the lowest number was recorded in T_2 (1.40) which was statistically similar with T_4 (1.63) and closely followed by T_1 (2.00), T_6 (2.33), T_5 (2.53) and T_3 (2.60), respectively (Table 3).

The highest percentage of infested pods plant^{-1} in number (13.69%) was recorded in T_7 which was followed and by T_3 (8.30%) and T_6 (7.45%), respectively. Again, the lowest percent in number was recorded in T_2 (3.09%) which was statistically similar with T_4 (4.02%) and closely followed by T_1 (4.88). Chickpea pod infestation percentage reduction over control at mid fruiting stage

Table 3. Effect of different doses of neem products and bio-control agents against chickpea pod borer by number at mid fruiting stage during the period from November, 2009 to March, 2010

Treatment	Chickpea pod by number			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
T_1	38.90 ab	2.00 cd	4.88 de	64.35
T_2	44.10 a	1.40 e	3.09 f	77.43
T_3	28.80 c	2.60 b	8.30 b	39.37
T_4	39.83 ab	1.63 de	4.02 ef	70.64
T_5	37.13 b	2.53 b	6.43 cd	53.03
T_6	29.07 c	2.33 bc	7.45 bc	45.58
T_7	26.50 c	4.20 a	13.69 a	--
$LSD_{(0.05)}$	5.949	0.464	1.576	--
CV(%)	9.58	10.92	12.96	--

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

in number was estimated for different botanicals and bio-control agents and the highest value (77.43%) was recorded for the T_2 and the lowest value (39.37%) from T_3. From the findings it is revealed that at mid fruiting stage spraying of neem oil @ 5 ml/L of water at 7 days interval performed maximum healthy pods and minimum infested pods as well as lowest percent of pod infestation in number followed by neem seed kernel @ 30 g/L of water at 7 days interval, on the other hand in untreated control treatment gave the minimum healthy pods, maximum infested pods and highest percentage of infestation under the trail followed by neem seed karnel @ 20 g/L of water at 7 days interval (Table 3). Korat *et al*. (2009) reported earlier that although all neem formulations were effective against pests and resulted in an increased yield. Similar results also reported by Butani and Mittal (1993), Jeyakumar and Gupta (1999), Bajpai and Sehgal (2000) and Visalakshimi *et al*. (2005).

4.2.2 Chickpea pod by weight (g)

Weight of healthy pods, infested pods and percent infestation of chickpea at mid fruiting stage for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Table 4). The highest weight of healthy pods per plant (214.89 g) was recorded in T_2 which was followed and with T_4 (193.63 g), T_1 (187.18 g) and T_5 (175.04 g) respectively, otherwise, the lowest weight was recorded in T_7 (121.08 g) which was closely followed with T_3 (142.22 g) and T_6 (162.37 g) respectively. The highest weight of infested pods per plant was recorded in T_7 (18.83 g), On the other hand, the lowest weight was recorded

Table 4. Effect of different doses of neem products and bio-control agents against chickpea pod borer by weight at mid fruiting stage during the period from November, 2009 to March, 2010

Treatment	Chickpea pod by weight (g)			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
T_1	187.18 b	11.68 bc	5.86 cd	56.53
T_2	214.89 a	7.88 d	3.54 e	73.74
T_3	142.22 d	13.88 b	8.92 b	33.83
T_4	193.63 b	9.58 cd	4.71 de	65.06
T_5	175.04 bc	13.32 b	7.06 bc	47.63
T_6	162.37 cd	13.40 b	7.71 bc	42.80
T_7	121.08 e	18.83 a	13.48 a	--
$LSD_{(0.05)}$	20.82	2.897	1.886	--
CV(%)	6.85	12.87	14.47	--

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

from T_2 (7.88 g) which was statistically similar with T_4 (9.58 g) and closely followed by T_1 (11.68 g), T_5 (13.32 g), T_6 (13.40 g) and T_3 (13.88 g) respectively.

The highest percent of infested pods plant^{-1} by weight (13.48%) was recorded in T_7 treatment, on the contrary the lowest percent by weight (3.54%) was recorded in T_2 treatment which was statistically similar with T_4 (4.71%) closely followed by T_1 (5.86%), T_5 (7.06%) and T_6 (7.71%) respectively. Chickpea pod infestation percentage reduction over control at mid fruiting stage in weight was estimated for different botanicals and bio-control agents and the highest value (73.74%) was recorded for the treatment T_2 and the lowest value (33.83%) from T_3.

From the findings it is revealed that spraying of neem oil @ 5 ml/L of water at 7 days interval performed maximum healthy pods and minimum infested pods as well as lowest percent of pod infestation by weight followed by neem seed kernel @ 30 g/L of water at 7 days interval, while in untreated control treatment gave the minimum healthy pods, maximum infested pods and highest percentage of infestation under the trail followed by neem seed kernel @ 20 g/L of water at 7 days interval (Table 4). Pod infestation is higher in most treatment on weight basis over number basis at mid fruiting stage under the present trial (Figure 2). Sarode *et al*. (1994) reported earlier that two sprays of NSKE 6% at 7 days interval provided significantly high larval reduction (69.45%) followed by two sprays of NSKE 5% (67.28%) and suggested that it may be used in managing *H. armigera* on chickpea. Similar results also reported by Jeyakumar and Gupta (1999), Bajpai and Sehgal (2000) and Visalakshimi *et al*. (2005).

4.3 Pod bearing status at late fruiting stage

4.3.1 Chickpea pod by number

Number of healthy pods, infested pods and percent infestation of chickpea at late fruiting stage for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Table 5). The highest number of healthy pods per plant (54.90) was recorded in T_2 (neem oil 5 ml/L of water at 7 days interval) treatment which was statistically identical (49.40) with T_4 (neem seed kernel @ 30 g/L of water at 7 days interval) which was closely followed (46.03 and 44.77) by T_1 (neem oil 3 ml/L of water at 7 days interval) and T_5 (*Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval) while, the lowest number (37.17) was recorded in T_7 (untreated control) treatment which was statistically similar (38.83 and 41.80) with T_3 (neem seed kernel @ 20 g/L of water at 7 days interval) and T_6 (*Bacillus thuringiensis* serovar *kurstak*i 1.5 ml/L of water at 7 days interval), respectively. The highest number of infested pods per plant was recorded in T_7 (6.40), whereas the lowest number was recorded in T_2 (2.27) which was statistically similar with T_4 (2.63) and closely followed by T_1 (3.00), T_5 (3.47), T_6 (3.67) and T_3 (3.90) respectively (Table 5).

The highest percent of infested pods $plant^{-1}$ by number (14.70%) was recorded in T_7 which was followed by T_3 (9.14%) and T_6 (8.08%) respectively. Again, the lowest percent in number (3.96%) was recorded in T_2 which was closely followed by T_4 (5.09%) and T_1 (6.08) respectively. Chickpea pod

Table 5. Effect of different doses of neem products and bio-control agents against chickpea pod borer by number at late fruiting stage during the period from November, 2009 to March, 2010

Treatment	Chickpea pod by number			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
T_1	46.03 bc	3.00 cd	6.08 d	58.64
T_2	54.90 a	2.27 e	3.96 e	73.06
T_3	38.83 de	3.90 b	9.14 b	37.82
T_4	49.40 ab	2.63 de	5.09 d	65.37
T_5	44.77 bcd	3.47 bc	7.23 c	50.82
T_6	41.80 cde	3.67 b	8.08 bc	45.03
T_7	37.17 e	6.40 a	14.70 a	
$LSD_{(0.05)}$	6.233	0.616	1.101	
CV(%)	7.84	9.56	7.99	

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

infestation percentage reduction over control at late fruiting stage in number was estimated for different botanicals and bio-control agents and the highest value (73.06%) was recorded for the treatment T_2 and the lowest value (37.82%) from T_3 treatment. From the findings it is revealed that spraying of neem oil @ 5 ml/L of water at 7 days interval performed maximum healthy pods and minimum infested pods as well as lowest percent of pod infestation by number followed by neem seed kernel @ 30 g/L of water at 7 days interval, while in untreated control treatment gave the minimum healthy pods, maximum infested pods and highest percentage of infestation under the trail followed by neem seed kernel @ 20 g/L of water at 7 days interval (Table 5).

4.3.2 Chickpea pod by weight (g)

Weight of healthy pods, infested pods and percent infestation of chickpea at late fruiting stage for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Table 6). The highest weight of healthy pods per plant (224.75 g) was recorded from T_2 treatment which was statistically similar with T_4 (202.30 g) which was closely followed by T_1 (185.28 g) and T_5 (179.17 g) on the other hand, the lowest weight was recorded in T_7 (138.50 g) which was statistically similar with T_3 (150.37 g) and T_6 (164.46 g) respectively. The highest weight of infested pods per plant (24.09 g) was recorded in T_7 treatment, whereas the lowest weight in T_2 (10.03 g) which was statistically similar and with T_1 (13.21 g) and T_4 (14.74 g) respectively (Table 6).

The highest percent of infested pods plant^{-1} by weight was recorded in T_7 (14.84%), whereas, the lowest percentage in weight was recorded in T_2 (4.27%) which was followed and with T_1 (6.73%) T_4 (6.81%), T_5(8.22%) and T_6 (8.49%) respectively. Chickpea pod infestation percentage reduction over control at late fruiting stage by weight was estimated for different botanicals and bio-control agents and the highest value (71.23%) was recorded for T_2 and the lowest value (35.65%) from T_3. From the findings, it is revealed that spraying of neem oil @ 5 ml/L of water at 7 days interval yielded maximum healthy pods and minimum infested pods as well as lowest percent of pod infestation by weight followed by neem seed kernel @ 30 g/L of water at 7 days interval, while in untreated control treatment gave the reverse results (Table 6). Pod infestation is higher in most treatment on weight basis over number basis at late fruiting stage under the present trial (Figure 3). Korat *et al*. (2009) reported that Safe clean, safe max, and neem oil are the botanical products use for controlling insect and pests. Safe clean is a detergent type products and safe max produced from mehogoni plant oil, whereas neem oil prepared from leaf of neem plant. Butani and Mittal (1993) studied the efficacy of neem seed kernel suspension and several conventional insecticides against *H. armigera* on chickpea and reported that all the tested insecticides significantly reduced the pest population and neem seed kernel suspension being equally effective.

Table 6. Effect of different doses of neem products and bio-control agents against chickpea pod borer by weight at late fruiting stage during the period from November, 2009 to March, 2010

Treatment	Chickpea pod by weight (g)			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
T_1	185.28 bc	13.21 c	6.73 c	54.65
T_2	224.75 a	10.03 d	4.27 d	71.23
T_3	150.37 de	15.77 b	9.55 b	35.65
T_4	202.30 ab	14.74 bc	6.81 c	54.11
T_5	179.17 bcd	15.81 b	8.22 bc	44.61
T_6	164.46 cde	15.16 b	8.49 bc	42.79
T_7	138.50 e	24.09 a	14.84 a	--
$LSD_{(0.05)}$	30.11	1.661	1.816	--
CV(%)	9.52	6.01	12.13	--

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

4.4 Pod bearing status at entire growing period

4.4.1 Chickpea pod by number

Statistically significant difference were shown in number of healthy pods, infested pods and percent infestation while different doses of neem products and bio-control agents used for controlling pod borer at entire growing period (Table 7). The highest number of healthy pods plant^{-1} (127.90) was recorded from T_2 (neem oil 5 ml/L of water at 7 days interval) treatment which was closely followed (116.53 and 111.03) with T_4 (neem seed kernel @ 30 g/L of water at 7 days interval) and T_1 (neem oil 3 ml/L of water at 7 days interval), respectively, while, the lowest number (84.17) was recorded in T_7 (untreated control) treatment which was statistically similar (88.33 and 92.97) with T_3 (neem seed kernel @ 20 g/L of water at 7 days interval) and T_6 (*Bacillus thuringiensis* serovar *kurstaki* 1.5 ml/L of water at 7 days interval), respectively. The highest number of infested pods plant^{-1} was recorded in T_7 (13.40), whereas the lowest number was recorded in T_2 (4.30) which was statistically similar with T_4 (5.10) and closely followed by T_6 (7.33), T_5 (7.40) and T_3 (7.90) respectively (Table 7).

The highest percent of infested pods plant^{-1} by number (13.74%) was recorded in T_7 treatment which was followed by T_3 (8.21%) and T_6 (7.32%) respectively. Again, the lowest percent in number was recorded in T_2 (3.25%) which was statistically similar and with T_4 (4.23%) and T_1 (5.24%) respectively and closely followed by T_5 (6.57). Chickpea pod infestation percentage reduction over control at entire growing period fruiting stage in number was estimated for different botanicals and bio-control agents and the highest value (76.35%) obtained from

Table 7. Effect of different doses of neem products and bio-control agents against chickpea pod borer by number at the entire growing period during the period from November, 2009 to March, 2010

Treatment	Chickpea pod by number			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
T_1	111.03 bc	6.17 c	5.24 d	61.86
T_2	127.90 a	4.30 d	3.25 e	76.35
T_3	88.33 d	7.90 b	8.21 b	40.25
T_4	116.53 b	5.10 cd	4.23 de	69.21
T_5	105.60 c	7.40 b	6.57 c	52.18
T_6	92.97 d	7.33 b	7.32 bc	46.72
T_7	84.17 d	13.40 a	13.74 a	--
$LSD_{(0.05)}$	10.27	1.072	1.008	--
CV(%)	5.56	8.18	6.17	--

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

the T_2 and the lowest value (40.25%) from T3 treatment. From the findings it is revealed that spraying of neem oil @ 5 ml/L of water at 7 days interval performed maximum healthy pods and minimum infested pods as well as lowest percent of pod infestation in number followed by neem seed kernel @ 30 g/L of water at 7 days interval, while in untreated control treatment gave the minimum healthy pods, maximum infested pods and highest percentage of infestation under the trail followed by neem seed kernel @ 20 g/L of water at 7 days interval (Table 7). The results obtained from the present study were similar with the findings of Sarode *et al.* (1994) and Jeyakumar and Gupta (1999).

4.4.2 Chickpea pod by weight (g)

Weight of healthy pods, infested pods and percent infestation of chickpea at entire growing period for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Table 8). The highest weight of healthy pods plant^{-1} (613.5 g) was recorded in T_2 which was closely followed (559.0 g and 524.5 g) with T_4 and T_1, respectively, while, the lowest weight (362.9 g) was recorded in T_7 which was statistically similar (404.1 g) with T_3. The highest weight of infested pods plant^{-1} (57.56 g) was recorded in T_7 which was followed (37.30 g, 36.88 g and 36.46 g) by T_5, T_3 and T_6, respectively whereas the lowest weight (23.22 g) was recorded in T_2.

Table 8. Effect of different doses of neem products and bio-control agents against chickpea pod borer by weight at the entire growing period

Treatment	Chickpea pod by weight (g)			
	Healthy	Infested	% infestation	Infestation decrease over control (%)
T_1	524.5 bc	31.50 c	5.66 d	58.66
T_2	613.5 a	23.22 d	3.64 e	73.41
T_3	404.1 ef	36.88 b	8.37 b	38.86
T_4	559.0 b	30.44 c	5.17 d	62.24
T_5	490.2 cd	37.30 b	7.11 c	48.06
T_6	449.8 de	36.46 b	7.50 c	45.22
T_7	362.9 f	57.56 a	13.69 a	--
$LSD_{(0.05)}$	47.10	3.951	0.838	--
CV(%)	5.44	6.14	9.45	--

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

The highest percent of infested pods plant-1 by weight was recorded in T7 (13.69%), again the lowest percent by weight was recorded in T_2 (3.64%) which was followed and with T_4 (5.17%) and T_1 (5.66%) respectively. Considering chickpea pod infestation percentage reduction over control at entire growing period fruiting stage in weight the highest value (73.41%) was recorded for the T2 and the lowest value (38.86%) from T3. From the findings it is revealed that spraying of neem oil @ 5 ml/L of water at 7 days interval performed maximum healthy pods and minimum infested pods, while in untreated control treatment gave the reverse results (Table 8). Pod infestation is higher in most treatment on weight basis over number basis throughout the growing period under the present trial (Figure 4).

4.5 Effect of temperature, rainfall and humidity on pod infestation of chickpea at different harvesting time

With increasing of temperature at different harvesting time, percent pod infestation of chickpea increasing and with increasing the temperature percent pod infestation also followed increasing trend (Figure 5) and it was highest in 5^{th} harvesting, when the highest mean temperature was raised at 30.35^0C. S Brevault *et al.* (2000) also reported that the developmental rate of the different life stages increased linearly with increasing temperature unto 30^0C. Neunzig (1991) observed that the incidence of fruit flies was the highest in February and the lowest in September. Percent pod infestation trend was found more or less similar when the mean rainfall was below 185 mm and the

trend was increasing when the mean rainfall was more than 265 mm (Figure 5).

4.6 Yield contributing characters and yield of chickpea

4.6.1 Plant height at harvest

Plant height of chickpea at harvest for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Appendix VII). The longest plant (53.30 cm) was recorded in T_2 treatment which was statistically identical (51.56 cm, 50.08 cm, 49.66 cm, 48.41 cm and 48.37 cm) with T_4, T_1, T_6, T_3 and T_5, respectively, while, the shortest plant (40.88 cm) was recorded in T_7 treatment (Table 9).

4.6.2 Number of branches plant^{-1}

Number of branches plant^{-1} of chickpea at harvest for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Appendix VII). The maximum number of branches plant^{-1} (17.57) was recorded in T_2 which was statistically similar (16.17, 16.17, 15.80, 15.13 and 14.90) with T_4, T_1, T_6, T_5 and T_3, respectively while, the minimum number (12.10) was recorded in T_7 (Table 9).

4.6.3 Number of leaves plant^{-1}

Number of leaves plant^{-1} of chickpea at harvest for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Appendix VII). The maximum number of leaves plant^{-1} (47.73) was recorded in T_2 which was statistically identical (46.83, 44.90) with T_4 and T_1 and closely followed (43.70 and 43.50) T_6, T_3 and T_5, respectively, while the minimum number (41.87) was recorded in T_7 (Table 9).

Table 9. Effect of different doses of neem products and bio-control agents against chickpea pod borer in terms of yield contributing characters

Treatment	Plant height (cm)	Number of branches /plant	Number of leaves /plant	Number of pods /plant	Pod length (cm)
T_1	50.08 a	16.10 a	44.90 abc	80.20 bc	2.73 a
T_2	53.30 a	17.57 a	47.73 a	95.20 a	2.90 a
T_3	48.41 a	14.90 a	43.70 bc	69.23 cd	2.77 c
T_4	51.56 a	16.17 a	46.83 ab	84.63 b	2.77 a
T_5	48.37 a	15.13 a	43.50 bc	76.00 bcd	2.63 ab
T_6	49.66 a	15.80 a	43.70 bc	73.30 cd	2.00 bc
T_7	40.88 b	12.10 b	41.87 c	65.90 d	1.40 c
$LSD_{(0.05)}$	6.313	2.665	3.151	10.26	0.701
CV(%)	6.99	9.73	8.97	7.42	9.13

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

4.6.4 Number of pods plant^{-1}

Number of pods plant^{-1} of chickpea at harvest for controlling pod borer by using some botanicals and bio-control agents showed statistically significant differences (Appendix VII). The maximum number of pods plant^{-1} (95.20) was recorded in T_2 treatment which was closely followed (84.63, 80.20 and 76.00) by T_4 and T_1 and T_5, respectively, while the minimum number (65.90) was recorded in T_7 treatment which was statistically identical (69.23 and 73.30) with T_3 and T_6 (Table 9).

4.6.5 Pod length

Pod length of chickpea for some botanicals and bio-control agents showed statistically significant differences (Appendix VII). The longest pod (2.90 cm) was recorded in T_2 treatment which was statistically identical (2.77cm, 2.73 cm and 2.63 cm) by T_4 and T_1 and T_5, respectively, while the shortest pod (1.40 cm) was recorded in T_7 treatment which was statistically similar (1.77 cm and 2.00 cm) with T_3 and T_6, respectively (Table 9).

4.6.6 Number of seeds pod^{-1}

Number of seeds pod^{-1} of chickpea showed statistically significant differences for controlling pod borer by using some botanicals and bio-control agents (Appendix VIII). The maximum number of seeds pod^{-1} (3.20) was recorded in T_2 which was statistically identical (3.07 and 2.97) by T_4 and T_1 and T_6, respectively, while the minimum number (2.20) was recorded in T_7 which was statistically identical (2.33 and 2.50) with T_3 and T_5 (Table 10).

4.6.7 Weight of 1000 seeds (g)

Weight of 1000 seeds of chickpea showed statistically significant differences for controlling pod borer by using some botanicals and bio-control agents (Appendix VIII). The highest weight of 1000 seeds (173.44 g) was recorded in T_2 which was statistically similar (171.52 g, 170.88 g, 165.76 g and 161.71 g) by T_4, T_1, T_5 and T_6, respectively, while the lowest weight (151.68 g) was recorded in T_7 treatment which was statistically identical (156.16 g) with T_3 (Table 10).

4.6.8 Yield plot^{-1}

Yield plot^{-1} of chickpea showed significant differences for controlling pod borer by using some botanicals and bio-control agents (Appendix VIII). The highest yield plot^{-1} (1.27 kg) was recorded in T_2 which was statistically similar (1.25 kg, 1.24 kg, 1.21 kg, 1.19 kg) with T_4, T_1, T_5, T_3 and T_6, respectively, while the lowest yield plot^{-1} (1.01 kg) in T_7 (Table 10).

4.5.9 Yield hectare^{-1}

Yield hectare^{-1} of chickpea showed statistically significant differences for controlling pod borer by using some botanicals and bio-control agents (Appendix VIII). The highest yield hectare^{-1} (2.12 ton) was recorded in T_2 which was statistically similar (2.08 ton, 2.06 ton, 2.02 ton, 1.99 ton and 1.98 ton) to T_4, T_1, T_5, T_3 and T_6, respectively, whereas the lowest yield hectare^{-1} (1.68 ton) was recorded in T_7 (Table 10).

Table 10. Effect of different doses of neem products and bio-control agents against chickpea pod borer in terms of yield contributing characters and yield

Treatment	Number of seeds/pod	Weight of 1000 seeds (g)	Yield (kg/plot)	Yield (t/ha)
T_1	2.97 ab	170.88 a	1.24 a	2.06 a
T_2	3.20 a	173.44 a	1.27 a	2.12 a
T_3	2.33 c	156.16 bc	1.19 a	1.99 a
T_4	2.07 ab	171.52 a	1.25 a	2.08 a
T_5	2.50 bc	165.76 ab	1.21 a	2.02 a
T_6	2.97 ab	161.71 abc	1.19 a	1.98 a
T_7	2.20 c	151.68 c	1.01 b	1.68 b
$LSD_{(0.05)}$	0.540	12.37	0.149	0.245
CV(%)	8.09	5.23	6.98	6.98

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

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

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

4.7 Economic Analysis

The analysis was done in order to find out the most profitable botanicals and bio-control agents based on cost and benefit of various components. The results of economic analysis of chickpea showed that the highest net benefit of Tk. 98,500 ha^{-1} was obtained in T_2 and the second highest was found Tk. 96,500 ha^{-1} in T_1 and T_4 (Table 11). The highest benefit cost ratio (1.93) was estimated for T_2 and the lowest (1.14) for T_6 under the trial. The highest BCR was found in T_2 may be due to the minimum infestation and cost compared to the other treatment components and the highest yield was produced in this treatment.

Table 11. Cost of chickpea production for different doses of neem products and bio-control agents in pod borer management practices

Treatments	Cost of pest Management (Tk.)	Yield (t/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost ratio
T_1	6,500	2.06	103,000	96,500	12,500	1.92
T_2	7,500	2.12	106,000	98,500	14,500	1.93
T_3	6,500	1.99	995,00	93,000	9,000	1.38
T_4	7,500	2.08	104,000	96,500	12,500	1.67
T_5	7,000	2.02	101,000	94,000	10,000	1.43
T_6	7,000	1.98	99,000	92,000	8,000	1.14
T_7	0	1.68	84,000	84,000	0	

Price of chickpea @ Tk. 50/kg

T_1: Neem oil @ 3 ml/L of water at 7 days interval

T_2: Neem oil @ 5 m1/L of water at 7 days interval

T_3: Neem seed kernel @ 20 g/L of water at 7 days interval

T_4: Neem seed kernel @ 30 g/L of water at 7 days interval

T_5: *Trichogramma evanescense* @ 0.5 gm/6 m^2 at 7 days interval

T_6: *Bacillus thuringiensis* serovar *kurstaki* @ 1.5 ml/L of water 7 days at 7 days interval

T_7: Untreated control

CHAPTER V

SUMMARY

The experiment was conducted at the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November, 2009 to March, 2010 to evaluate the performance of some bio-control agents and botanicals for combating pod borer of chickpea. Seeds of chickpea variety BARI Chola-5 were used as a test crop for the study. The experiment consists of 7 treatments as T_1: Neem oil 3 ml/L of water at 7 days interval, T_2: Neem oil 5 m1/L of water at 7 days interval, T_3: Neem seed kernel @ 20 g/L of water at 7 interval, T_4: Neem seed kernel @ 30 g/L of water at 7 interval,T_5: *Trichogramma evanescense* @ 0.5 gm/6m^2 at 7 days interval, T_6: *Bacillus thuringiensis* serovar *kurstaki* 1.5 ml/L of water at 7 days interval and T_7: Untreated control. The experiments were laid out in Randomized Complete Block Design (RCBD) with three replications.

At early fruiting stage the highest percent of infested pods plant^{-1} by number (12.04%) was recorded in T_7. On the other hand, the lowest percent by number (2.16%) was recorded in T_2 and in weight the highest percent of infested pods plant^{-1} by weight (12.41%) was recorded in T_7, again the lowest percent in weight (2.92%) was recorded in T_2. At mid fruiting stage the highest percent of infested pods plant^{-1} by number (13.69%) was recorded in T_7 and the lowest percent by number (3.09%) was recorded in T_2. Again, the highest percent of infested pods plant^{-1} by weight (13.48%) was recorded in T_7; again the lowest

percent in weight (3.54%) was recorded in T_2. At late fruiting stage the highest percent of infested pods plant^{-1} by number (14.70%) was recorded in T_7 while, the lowest percent by number (3.96%) was recorded in T_2. The highest percent of infested pods plant^{-1} in weight (14.84%) was recorded in T_7; again the lowest percent by weight (4.27%) was recorded in T_2. In the entire growing period the highest percent of infested pods plant^{-1} by number (13.74%) was recorded in T_7 whereas, the lowest percent by number (3.25%) was recorded in T_2. The highest percent of infested pods plant^{-1} by weight (13.69%) was recorded in T_7; again the lowest percent by weight (3.64%) was recorded in T_2.

The longest plant (53.30 cm) was recorded in T_2 treatment and the shortest plant (40.88 cm) was recorded in T_7. The maximum number of branches plant^{-1} (17.57) was recorded in T_2 while, the minimum number (12.10) was recorded in T_7. The maximum number of leaves plant^{-1} (47.73) was recorded in T_2 and the minimum number (41.87) was recorded in T_7. The maximum number of pods plant^{-1} (95.20) was recorded in T_2 and the minimum number (65.90) was recorded in T_7. The longest pod (2.90 cm) was recorded in T_2 while the shortest pod (1.40 cm) was recorded in T_7. The maximum number of seeds pod^{-1} (3.20) was recorded in T_2 again the minimum number (2.20) was recorded in T_7. The highest weight of 1000 seeds (173.44 g) was recorded in T_2 while the lowest weight (151.68 g) was recorded in T_7. The highest yield hectare^{-1} (2.12 ton) was recorded in T_2 whereas the lowest yield hectare^{-1} (1.68 ton) was recorded in T_7. The highest benefit cost ratio (1.93) was estimated for T_2 and the lowest (1.14) for T_6 under the trial. The highest BCR was found in the treatment T_2 may be due to the minimum infestation and cost compared to the other treatment components and highest yield.

CONCLUSION AND RECOMMENDATION

The study revealed that among the different treatments T_2 treatment (Neem oil 5 m1/L of water at 7 days interval) showed best performance in terms of reduction of pod infestation, improvement of yield contributing characters and finally increased pod yield. Benefit Cost Ratio (BCR) was highest in the same treatment. On the other hand, T4: (Neem seed kernel @ 30 g/L of water at 7 days interval) also showed more or less similar performance under different treatments of the present study.

These two treatments utilized Neem oil and Neem seed kernel which supplemented for combating chickpea pod borer and might be tested with *Bacillus thuringiensis* serovar *kurstaki* 1.5 ml/L of water in future. However, on-farm or and/or on-station trials may be undertaken in order to confirm the validity of these results. Other botanicals such as lantana leaf extract, marigold leaf extract, Bankolmi leaf powder etc. and bio-control agents may be included for further study.

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