Bio-ecological studies on pod borer [*Helicoverpa armigera* (Hubner) Hardwick] and its management through bio-pesticides in chickpea

Ravindra Kr. Harsoliya[*]
Research Scholar

Dr. T. Hussain[**]
Major Advisor

ABSTRACT

Investigations were carried out on "Bio-ecological studies on pod borer [*Helicoverpa armigera* (Hubner) Hardwick] and its management through bio-pesticides in chickpea" at Agronomy farm, Rajasthan College of Agriculture, Udaipur during *rabi* 2005-06.

The gram pod borer, *H. armigera* started appearing on gram crop during the fourth week of October and touched the peak in the third week of November. The gram pod borer reappeared in the last week of December and reached to a peak in the first week of February. The larval population of *Helicoverpa armigera* was positively correlated to the atmospheric temperature, but negatively correlated to the relative humidity, though the correlation coefficient values were non-significant.

Parasitization was observed in November and the maximum parasitization (24%) due to larval parasitoid, *Campoletis chloridae* Uchida was recorded in the last week of November; whereas in February the gram Caterpillar parasitization (20%) was recorded due to pupal parasitoid, *Carcelia illota* Curran.

The efficacy of different bio-pesticides in a descending order were as follows: *M. anisopliae* (oil formulation) > *M. anisopliae* (aqueous formulation) > *M. anisopliae* (water emulsion) > Karanj oil 2% > *Pseudomonas aeruginosa* > Neem oil 2% > NSKE 10%.

[*] P.G. Scholar, Department of Agricultural Zoology & Entomology, RCA, Udaipur.
[**] Asstt. Prof., Department of Agricultural Zoology & Entomology, RCA, Udaipur.

1. INTRODUCTION

Chickpea is commonly known as gram or bengal gram and it is considered as the “king of pulses”. Gram is grown extensively in India covering about 6.5 million hectares area with an annual production of 5.8 million tonnes having an average productivity of 888 kg/ha (Anonymous, 2005). Rajasthan is a major gram growing state in India. In Rajasthan, at present the area under this crop is 11 lakh hectares with a production of 7.1 lakh tonnes and the productivity is 633 kg/ha (Anonymous, 2004). Due to its high nutritional value chickpea forms an important component of the vegetarian diet. Owing to its availability to fix atmospheric nitrogen, gram is suitable for crop rotation (Kudale *et al.,* 2002). Grain legumes play an important role in overcoming the quantitative and qualitative protein requirement for a large part of humanity (Bhatt and Patel, 2001).

Among the various factors that limit the production of gram, damages inflicted by insect pests are important. About sixty insect species have been reported to feed on chickpea (Reed and Pawar, 1982). Gram pod borer [*Helicoverpa armigera* (Hubner)] is the major pest of chickpea, which has been reported from almost all chickpea growing countries (Suganthy, 2000). The pest appears throughout the year on different crops, depending upon the cropping system. The gram pod borer has been recorded on over 20 crops and 180 wild hosts in India (Derek and Russell, 1999); including pigeonpea, cotton, tomato, groundnut, okra and sunflower in India (Rote and Thakkar, 2001). Its high biotic potential, omnivorous food habit and suspected migratory behaviour make it a more serious pest. Freshly emerged larva feed on tender leaves and then reach to the flower bud. At pod stage, the larvae make a hole into the pods and feed from within the pod (Bhatt and Patel, 2001). World wide, *H. armigera* results in over $2 billion losses, despite over $ 500 million worth of pesticides used to minimize the losses due to this pest (Sharma, 2001).

A large number of natural enemies, more than 70 species of parasitoids and 60 species of predators are known to attack *H. armigera* in India (Romeis and Shanower, 1996). Compared to other host plants (e.g. cotton and sorghum), there were relatively few natural enemies on *H. armigera* in chickpea. Nikam and Gaikwad (1989) reported that among 100 species of parasitoids parasitizing *H. armigera, C. chloridae* is

predominant and may parasitize more than 30 per cent of *H. armigera* larva infesting chickpea (Romeis and Shanower, 1996).

In recent years much interest has been evinced in the use of plant products and microbes to control agricultural pests following environmental and health hazards due to synthetic organic pesticides. Plant products have been used since long for the control of crop pests. Among the different components of integrated pest management, the microbes and plant products play an important role in regulating the pest population. Shankar *et al.* (1992) has reported their effectiveness against a number of crop pests.

The present investigations were carried out with the following objectives:

1. To study the population dynamics of the pod borer, *Helicoverpa armigera* (Hubner) Hardwick under field conditions.
2. To assess the extent of natural parasitism of *H. armigera* by the larval parasitoid, *Campoletis chloridae* Uchida on chickpea.
3. To evaluate the bioefficacy of some botanicals and microbial pesticides for the management of the pest.

2. REVIEW OF LITERATURE

The present investigation was carried out to study the "Bio-ecological studies on pod borer [*Helicoverpa armigera* (Hubner) Hardwick] and its management through bio-pesticides in chickpea". Pertinent literature in relation to the proposed work has been reviewed here below:

2.1 POPULATION DYNAMICS OF POD BORER:

Bhatnagar and Davies (1978) reported maximum population of the gram pod borer in the month of January during 1975-76 and 1976-77. Singh and Singh (1978) concluded that weather factors in the preceding period had a stronger influence on the pest incidence. Patel (1979) observed that the rains prior to sowing and frequently during crop growth, particularly in January (coldest month) enhance the population build-up of this pest. High humidity (60-75%) and temperature (10-15°C) during January accompanied with rains 3-5 cm at a time may be critical factor for multiplication of the pest. Dakwale and Singh (1980) reported that infestation of *H. armigera* on chickpea started in January and reached its peak in February. Vaishampayan and Veda (1980) observed that a rainfall of 250 mm or more in September and October highly favoured the build-up of first generation larval peak in pre-flowering stage. Winter rains in December, January and February about 25 mm and above per month, proved highly conducive to the pest and determined the size of second major brood in the pod formation stage of the crop. Minimum daily temperature 10 to 15°C was found to be the optimum for the activity of the pest. They further reported that relative humidity and pest incidence on gram had highly significant negative correlation, relative humidity between 50 to 70 per cent was found favourable to pest population. The relative humidity below 75 per cent was considered an alarming level and a sure indicator of high population build up of the pest on gram during the major active period from December to February.

According to Odak (1981) the gram pod borer, *H. armigera* remained active from September to March on various crops like jowar, maize, soybean, arhar, sunflower, safflower, lentil, linseed and pea. The population was found to low during off season i.e. from April to August. Yadav and Yadav (1983) recorded the maximum

population of larvae of *H. armigera* in December and January from the second week of March to the end of April on chickpea.

In southern Rajasthan, *H. armigera* appeared on gram crop in the second week of January and continue till the end of February (Kushwaha, 1983). Kaushik and Naresh (1984) observed that the larvae of *H. armigera* occurred throughout the growth period of the crop, the density being <0.81 larvae/m^2 at the pod stage. Metho *et al.* (1985) reported that the pod borer, *H. armigera* infested the tender leaves and shoots during the active vegetative stage and the grand growth period, and later on the pods at the pod formation. The incidence of the pest commenced during the active vegetative state of grain in the first week of January. The population gradually built-up, reaching peak during end of February to March and all of a sudden declined in the maturity of pods by the end of March. They further reported that the pest continued to build-up, influenced by uniform average temperature (15±3°C) and a fair relative humidity (75 ± 10 per cent) from first week to 9^{th} week (January to February). Tripathy and Sharma (1985) observed that the important factors, indicating the probability of population build-up, were relative humidity (below 70%) and low rainfall. Temperature range of 12-21°C was the most favourable for the pest development. Yadav *et al.* (1986) reported that the peak period of infestation of *H. armigera* was from December to February on chickpea and the pest almost become inactive by May.

At Udaipur (Rajasthan) the larval incidence of *H. armigera* recorded on gram crop during 1984-85 revealed that the incidence of pest commenced during mid January and increased gradually in the month of February, so as to reach its peak by the end of March. The pest population declined rapidly within two week onward (Anonymous, 1988b). Prasad *et al.* (1989) observed that on crops sown on 12^{th} or 22^{nd} October, the larval population was fairly low during December; during this month the minimum daily temperature was a mean of 7.5 per cent. The population of *H. armigera* was highest in the first week of March, when chickpea crop was sown on 22^{nd} October.

The incidence of *H. armigera* started by first week of January and reach its peak by March (Ravi and Verma, 1997). The pest activity was observed during November to January-February, however its population was at peak during December (Patel and Koshiya, 1997). Borah (1998) reported that the maximum (38.8 per cent)

borer infestation was in late sowing of chickpea (December, 30) and minimum (20.2 per cent) was in early sowing (October, 15). Patel and Koshiya (1999) concluded that in chickpea crop, the pests were first observed in the third week of November and reached a peak in the third week of December, when the crop was at the podding sage, in this crop, the pest was active from November to February. Among the various factors, maximum and minimum temperature as well as vapour pressure showed decreasing trends which contributed to population fluctuations.

Rao *et al.* (2001) reported that the incidence of *H. armigera* on chickpea was noticed at the flowering stage, 38 days after sowing (2 larvae/10 plants). The peak incidence was recorded on 87 old crop (20 larvae/10 plants) during the month of January. Krishna *et al.* (2004) observed that the number of trap catches of *H. armigera* increased with the advancement of crop stage and increase in temperatures. Trap catches increased by 3 to 6-fold per week between the 7^{th} or 10^{th} standard week. The flowering and podding or pod maturation stages of the crop, coincided with the increase in moth population.

2.2 NATURAL PARASITIZATION:

Bilapate (1981) recorded the seasonal incidence of *H. armigera* larval and pupal parasites and found that C*ampoletis chloridae* and *Carcelia* sp. were the most important larval parasitoids. Parasitism by *Campoletis chloridae* on *H. armigera* reached 23% on cotton in December. Nikam and Gaikwad (1989) reported that among to 100 species of parasitoids parasitizing H. armigera, *Campoletis chloridae* is predominant. Srinivas (1989) concluded that the maximum parasitization of *H. armigera* larvae (43.9%) was recorded for *Compoletis chloridae* during the first 2 week Of December and minimum parasitization (12%) during last week of January.

Kushwaha (1989) indicate that *Banchopsis, Campoletis, Eriborus, Enicospilus, Palexorista, Carcelia*, and *Goniphthalmus* are apparently more important among the larval/pupal parasitoids of *H. armigera* in India. Pawar *et al*. (1989) observed that *Campoletis chloridae* was the most common parasitoid in most years (from 1974 to 1983) parasitism was highest in September and lowest in May. At one site during 1977-83, the average parasitism of 1^{st} to 3^{rd} instar larvae by *C. chloridae* on sorghum, chickpea, pearl millet, groundnut and pigeonpea was 44.2, 33.1, 32.6, 7.1 and 4.2% respectively.

When laboratory-reared *Campoletis chloridae* released on *H. armigera* infested microplots of chickpea, it resulted in 30% parasitism (Anonymous, 1992 a). Rao *et al*., (1994) observed that 4-10% parasitization of larvae of *H. armigera* by the larval parasitoid *Campoletis chloridae*. According to Romeis and Shanower (1996) more than 70 species of parasitoids and 60 species of predators are known to attack *H. armigera* in India. Out of them the larval parasite, *Campoletis chloridae* may parasitize more than 30% of *H. armigera* larvae in chickpea. Ravi and Verma (1997) concluded that population of *Campoletis chloridae* followed the host population and declined after 9th standard week due to rise in environmental temperature.

The larval parasitoid *Campoletis chloridae* has been recorded as the most important mortality factor. Parasitism due to *C. chloridae* ranged from 0.98 to 68.50% throughout the crop season. The maximum parasitism was recorded during the third week of February 1999 when the minimum mean temperature and relative humidity were 11.9°C and 95% respectively (Kaur *et al.,* 2000). Tikar *et al*. (2001) recorded maximum parasitization of *H. armigera* larvae by *Campoleties chloridae* and *Eriborus* spp. in *Lagascea mollis* was observed than the larvae collected from cotton crop. The highest parasitization (40.7%) was observed in larvae collected from *L. mollis* during 38th meteorological week, where as highest parasitization of 11.1% was observed in the larvae collected from cotton during 35th and 38th meteorological weeks.

Kaur *et al.* (2004) studied on natural parasitism of *H. armigera* by *Campoletis chlorideae* on Chickpea cultivars L 550, BG 1053, PBG1, PBG5 and PDG4 at different location in Jalandhar district of Punjab India during 2002-03. They concluded that the parasitoid population varied from 0.02-1.50 cocoons per meter row length and the larval population ranged between 0.86 and 14.50 larvae per meter row length. The highest number of cocoons were recorded on PBG 5(0.88) followed by L550 (0.74). The *H. armigera* population was also high on PBG 5 (9.38 larvae/m row length followed by L 550 (6.75 larvae/m row length).

2.3 BIOEFFICACY OF BIOPESTICIDE:

Babu and Rajasekaran (1984) reported that the vegetable products neem oil at 3 or 5 percent permitted the lowest damage rate and karanj oil at 3 or 5% the highest yields in chick pea. Singh *et al* (1985) observed that the ethanolic extract of neem

kernels reduced the incidence of *Helicoverpa armigera*. Hongo and Karel (1986) concluded that aqueous extract from neem seed kernels caused deterrent effect and antifeedent effect against *H. armigera*. Sharma and Dahiya (1986) reported that the treatment of chickpea crop with neem seed oil reduced the population of *H. armigera*, pod damage and increased grain yield. Prasad *et al* (1987) reported that the larval population of *H. armigera* was highest (2.2-2.5 larvae/m row) in plots treated with karanj oil and untreated plots and lowest in neem oil treated plots. Sehgal and Ujagir (1990) observed that the neem seed kernel extract at 5% was less effective than other insecticides but still significantly better than the control. Gupta *et al.* (1990) reported that neem oil and karanj oil, both treatment significantly reduced the larval population of *H. armigera*.

According to Sachan and Katti (1993), neem seed kernel extract (NSKE) and neem leaf extract (NLE) both at 5 percent provided significant and cost effective control of *H. armigera* compared to conventional insecticides in chickpea. Sachan and Lal (1993) reported that all the treatments, (neem seed kernel extract, neem leaf extract, neem oil and other insecticides) reduced the pest population, but neem seed kernel extract and neem leaf extract were more effective for controlling the pest on chickpea than on pigeonpea. Shinha (1993) observed that neem oil and neem seed kernel extract (5.0%) sprayed at an interval of 10 days gave a 2- fold reduction in population of *H. armigera* compared with the untreated control. Jaglan *et al.* (1997) reported that the Chloroform : Methanol (9:1) neem seed and leaf extracts showed better insecticidal properties than methanol extracts. However, neem seed extract in chloroform: methanol (9:1) was the most promising in causing adverse morphogenic effect on various biological parameters of *H. armigera.* Early stage larvae were more sensitive to the exposure of neem extracts than advanced stage larvae. Sharma and Sheikher (1997) concluded that chickpea leaves treated with different concentration of neem leaf extract were fed to 1^{st}, 2^{nd} and 3^{rd} instar larvae for 48 h larval mortality ranging from 16 to 86% was recorded. Wanjari *et al.* (1998) reported that all the treatments (HaNPV, Dipel, neem seed extract and endosulfan either alone or in a combination of two products) were effective in reducing larval population of *H. armigera* and produced greater grain yield compared to the untreated control. According to Chakraborti and Chatterjee (1999) all the treatments (azadirachtin,

azadirachtin-iodine, neem seed kernel extract (NSKE) and neem oil) gave effective result against to check the population of *H. armigera*.

Neem oil at 2.0%, neem seed kernel water extract (NSKWE) at 5.0%, and karanj oil at 2% were effective against the pest compared to control and resulted in significant reduction in pod damage at maturity and increased grain yield. Among these botanical insecticides, karanj oil resulted in the highest grain yield (12.9q /ha) with 44% pod damage in 1992-93, while neem oil resulted in the highest yield (16.5 q/ha) with 59% pod damage in 1993-94 (Bajpai and Sehgal, 1999).

Kulat *et al.* (2001) observed that the chickpea crop treated with the leaf extract of tobacco and seed extract of *Pongamia pinnata* (5%) and neem seed kernel extract (5%) exhibited low level of the pest population built up compared to control. Bajpai and Sehgal (2003) reported that the methanol and chloroform extracts of neem seed kernel and nicotine sulphate were very effective against the oviposition of *H. armigera* female moth where as water extract of neem seed kernel and neem oil were effective at higher concentration only. Neem seed kernel methanol extract at 0.1, 0.15 and 0.2%, chloroform extract at 0.15 and 0.2% and butanol extract at 0.2% strongly inhibited oviposition.

The relationship between *Heliothis armigera* and the entomopathogenic fungus *Metarrhizium anisopliae* var. *anisopliae* was studied in the laboratory at 27°C. Treatment with $1.8x\ 10^9$ conidia/ml caused 80-100% mortality of larvae in all 5 instars, prepupae and pupae within 2-10 days, with 1^{st} and 2^{nd} instar larvae having 100 and 75% mortality, respectively, within 48 h. Eggs and adults were not affected, but eggs laid by treated females were sterile (Gopala Krishnan and Narayanan, 1989). Prasad *et al*. (1990) observed that *Beauveria bassiana* was found to be the most virulent, recording the lowest LC_{50} of 2.17×10^5 conidia/ml against 2^{nd}-instar larvae of *Heliothis armigera*. Gopalkrishnan and Narayanan (1990) concluded that *Beauveria bassiana* was pathogenic to all stage of *Heliothis armigera*, causing 60-100% mortality of larvae and 100% mortality of eggs when individuals of *H. armigera* were dipped into a suspension of 1.0×10^7 conidia/ml. Sridevi *et al.* (2004) reported that the individual treatment of Btk (0.05 to 0.19%) and *Beauveria bassiana* (1.6×10^5 to 2.5×10^5 spores/ml) were at par resulting in 53.0-75.6 and 60.4-75.3 per cent larval mortality, respectively.

The susceptibility of adults of *Oryctes rhinoceros* (L.) to infections with *Beauvaria bassiana*, *Beauveria tenella*, *Metarrhizium anisopliae*, *Paecilomyces fumosoroseus* and *Nomuraea* (*Spicaria*) *rileyi* was studied by spraying titrated suspensions of spores on to the insect integument. The results shows to beetles were susceptible only to strains of *M. anisopliae* of the major type (Ferron *et al.*, 1975).

Prado (1980) reported that *Beauveria bassiana* was pathogenic to the larvae of *Otiorhynchus sulcatus* at a rate of 4 x 10^6 spores/cm^3 soil. *Metaryhizium anisopliae* seemed even more effective, being pathogenic at a rate of 1 x 10^6 spores/cm^3 but ultimately gave complete kill even at 1 x 10^5 spores/cm^3. In a glasshouse trial, it prevented all damage by the larvae. Vignes and Vignes (1987) tested a commercial preparation of the entomopathogenic fungus *Metarrhizium anisopliae* against adults of the cercopid *Aeneolamia varia saccharina* on sugarcane. The insects did not appear to be infected the fungus.

Burdeos and Villacarlos (1988) observed that all the fungi (*Metarrhizium anisopliae, Paecilomyces lilacinus* and *Beauveria bassiana*) pathogenic to the insect (*Cylas formicarius*) at different degree. *Metarrhizium anisopliae* gave the lowest LC_{50} of 8.42 x10 spores/ml. Thang and Shepard (1988) reported that, *Nilaparvata lugens* mortality due to infection by *Metarrhizium anisopliae* or *Beauveria bassiana* at concentration of 5 x 10 to the sixth power-5 x10 to the seventh power conidia/ml suspension was low ranging from 6.6 to 20% for the nymphal stage and 43.3 to 50% for the adult stage, 10-12 days after treatment. Gallego and Galliego (1989) observed *Beauvaria bassiana* which had a consistently higher spore count was found to be more effective against *Tirathaba rufivena*, *Promecotheca cumingii* and *Plesispa reichei* as compared to *Metarrhizium anisopliae* which had a lower spore count against the three pest mentioned. Pandit and Samanta (1995) concluded that, mortality of the pest (*Spilosoma obliqua*) was 74-78% and 75-91% in the case of *Beauveria bassiana* and *Metarrhizium anisopliae*, respectively.

Gardezi and Mahmood (1998) reported that, nine species of fungi including *Metarrhizium anisopliae* were infectious to *Chilo partellus*. Yadav *et al*. (2000) studied on bio control efficacy of entomopathogenic fungus, *Metarrhizium anisopliae* against first, second and third instar of white grub (*Holotrichia consanguinea* Blanch.) The result showed that, the highest mortality rates (70%) for first instar grubs was recorded upon treatment with 1 x 1011 spores for 16 days. Second instar

grubs exhibited the highest MR (60%) when treated with 1x1011 and 5x1010 spores/ml soil for 30 days. Third instar grubs showed the highest MR (50%) after treatment with 1x1011 and 5x1010 for 25-30 days, and with 1x1010 for 30 days.

Odak *et al*. (1982) reported that, Bactospeine (*Bacillus thuringiensis* var. *thuringiensis*) and Thuricide were highly pathogenic to larvae of *Heliothis armigera* causing 70-100% mortality in the laboratory and 20-65% mortality in the pot experiment. Khaliqe *et al*. (1989) evaluated Bactospeine WP (*B. thuringiensis* subsp. *thuringiensis*) and the standard strain HO 1 S 1980 (*B. thuringiensis* subsp. *kurstaki*) against 1st and 3rd instar larvae of the noctuid *Heliothis armigera* in the laboratory at 26°C and 65-80% RH. The LC_{50}s of *B.t. thuringiensis* for 1st and 3rd instar larvae were 63.52 and 177-60 Imu/ml, respectively, after 7 days exposure. The LC_{50} for *B.t. kurstaki* with 1st and 3rd instar larvae were 56.16 and 126.40 Imu/ml. Broza and Sneh, (1994) reported that *Heliothis armigera* Hubner usually accompanied the major pest at low to medium population densities (2-4 larvae per meter row). In 38 of 40 commercial fields (2-35 ha each), application of *B. thuringiensis* suppressed pest population to levels below the economic threshold.

Pooled data of 2 years showed suppression of larvae population due to various treatments from the 3rd day onwards. The lowest larvae number was recorded in treatment with Delfin (2.31 larvae on 5 plants). An increase in the larval count was observed from the 11th day onwards. No significant difference were observed in all the treatments on the 14th day though they was significant better than the untreated control (Pharindera Yadav *et al*., 2004). Mortimore *et al*. (1971) reported that, the larvae of *Tenebrio molitor* showed a marked difference in susceptibility to *Pseudomonas aeruginosa* and *Serratia marcescens* when they were injected into them in laboratory. One or two bacteria of strain P11-1 of *P. aeruginosa* killed over half the larvae in 5 days, where as 4x106 bacteria of *S. marcescens* killed about half the larvae in 4 weeks. Verma and Singh (1987) observed that *Bacillus thuringiensis* infecting *Latoia bicolor* (*Parasa bicolor*); *Bacillus sphaericus* and *streptococcus* sp. infecting *Chilo auricillius*; and (in the laboratory) *Pseudomonas aeruginosa* infecting *Spodoptera litura*.

The larvae of *Spodoptera litura* were found to be infected with *Bacillus thuringiensis, Pseudomonas aeruginosa, Streptococcus* sp., *Metarrhizium anisopliae* and *Entomophthora* sp. The mortality of *S. litura* on cauliflower due to these

pathogens was 30.5 and 19.6% in 1975 and 1976, respectively (Prasad and Kushwaha, 1990). Poprawski and Yule (1990) reported that all 5 species of bacteria (*Bacillus cereus*, *B. popilliae*, *Micrococcus nigrofasciens*, *Pseudomonas aeruginosa* and *Serratia marcescens*) were pathogenic to larvae by injection but only the spore-forming *B. popilliae* and *B. cereus* were infectious when administered orally.

Pseudomonas aeruginosa was identified as a facultative injection of the pathogen within larvae and pre-pupal was more effective at killing the insects (with a median lethal dose (LD_{50}) of 9×10^2 to 2×10^3 bacteria/insect) than inoculation by force feeding (LD_{50} of 10^5 to 4×10^5 bacteria/insect) or by wading (to wet the abdomen) in a suspension of the pathogen (LD_{50} of 10^5 to 2×10^5 bacteria/insect). Injection of 3×10^3 bacteria/insect killed 69% of larvae; small larvae were more susceptible (LD_{50} of 9×10^2 bacteria/larvae) than either larger larvae (LD_{50} of 10^3 bacteria/larva) or pre-pupal (LD_{50} of 2×10^3 bacteria/pre-pupa). The median time to death of the small larvae following injection of *P. aeruginosa* was about 6 days but that following force feeding or wading was about 8 days (Banerjee and Dangar, 1995).

The most prevalent bacterial taxon from larval and pupal cadavers of *Diatraea grandiosella* Dyer and *Diatreaea crombidoides* Grote. was *Enterococcus faecalis but Bacillus* sp., *Pseudomonas aeruginosa* and *Serratia marcescens* were frequently isolated as well (Inglis *et al*., 2000). Schneider and Dorn (2001) concluded that *Pseudomonas aeruginosa* and *Pseudomonas putida* showed a profound differential infectivity after inoculation in *Oncopeltus fasciatus*. Whereas *P. putida* has no significant impact on nymphs, *P. aeruginosa* kills all experimental animals within 48 hours. Osborn *et al*., (2002) isolated and identified 29 bacterial strains from live, dead and experimentally infected *Hylesia metabus* Crammer larvae, and evaluated their pathogenic mortality. The bacteria which caused mortality in the larvae were : *Pseudomonas aeruginosa* (60-93.3%), *Proteus vulgaris* (20%), *Alcaligenes faecalis*, *Planococcus* sp. and *Bacillus megaterium* (10%).

According to Kulkarni *et al*.(2005) the highest grain yield was recorded in NPV treated plots (8.25q/ha) followed by *Nomuraea rileyi* (7.44q/ha) and *M.anisopliae* (7.42q/ha) while *M.anisopliae* recorded the lowest pod damage (18.06%) followed by *Nomuraea rileyi* (18.64%) and NPV (20.07%). Singh and Yadav (2005) reported that *M.anisopliae* and the *Bacillus thuringiensis* subs. *Kurstaki* based formulation proved less effective than either *Beauveria bassiana* .

3. MATERIALS AND METHODS

The present investigation entitled, "Bio-ecological studies on pod borer [*Helicoverpa armigera* (Hubner) Hardwick] and its management through bio-pesticides in chickpea" was carried out at the Agronomy Farm, Rajasthan College of Agriculture, Udaipur from October 2005 to March 2006. The details of the techniques followed and materials used during the course of investigation are described in this chapter under suitable heads.

3.1 EXPERIMENTAL SITE:

The experiment was laid out at Agronomy farm, Rajasthan college of Agriculture, Udaipur, which is situated at an elevation of 582.17 meters above mean sea level and at latitude of 24°34' North and longitude of 73°42' East.

3.2 CLIMATIC CONDITIONS:

Udaipur has a sub-tropical climate characterized by mild winter and summer. The average rainfall ranges between 500-700 mm per year of which more than 90 percent is received during mid June to September with scanty showers during the winter season. The maximum and minimum temperature of Udaipur ranges from 23-41°C and 5.8-23°C respectively.

Weekly meteorological observations of atmospheric temperature, relative humidity and rainfall during the period of experimentation (October, 2005 to March, 2006) were taken and have been presented in Table 3.1.

3.3 FIELD PREPARATION AND SOWING:

The experimental field was prepared during the first week of October by ploughing with the help of disc plough followed by cross harrowing. A well-pulverized field was obtained for sowing of gram. The experiment was laid out in a randomized block design having a plot size of 5m x 5m for each replication.

The seeds of gram variety "Dahod Yellow" were sown on the 7th October, 2005 maintaining a row to row spacing of 30 cm and plant to plant distance of 10 cm. Irrigation, hoeing, weeding and other cultural practices were followed as per the recommendations.

3.4 SPECIFIC DETAILS OF THE EXPERIMENT:

3.4.1 Population Dynamics of the Pod Borer, *Helicoverpa armigera* (Hubner):

To record the population dynamics of the pod borer, an experiment was laid out in plots measuring 5m x 5m; gram variety "Dahod Yellow" was grown maintaining a row to row and plant to plant distance of 30cm x 10cm, respectively. Other recommended agronomic practices were followed.

3.4.1.1 Observation:

Weekly observations on the pest population using standard sampling techniques were taken. Record of climatic data (atmospheric temperature and relative humidity) was made to study the influence of abiotic factors on the pest population. The gram pod borer population was recorded on per-meter-row basis during early morning hours, between 7.30 AM to 9.00 AM, randomly selecting three rows per plot. The linear relationship between gram pod borer population and the abiotic environmental factors was established.

The pest populations were correlated to the weather parameters *viz.*, atmospheric temperature and relative humidity by using simple correlation coefficient formula:

$$r_{X1Y1} = \frac{X_1Y_1 - \frac{(\sum X_1)(\sum Y_1)}{n}}{\sqrt{\left(\sum X_1^2 - \frac{(\sum X_1)^2}{n}\right)\left(\sum Y_1^2 - \frac{(\sum Y_1)^2}{n}\right)}}$$

Where,

r_{X1Y1} = Simple linear correlation coefficient.

X_1 = Meteorological parameter (independent variable)

Y_1 = Population of pest (dependent variable)

n = Number of observations.

3.4.2 Natural Parasitization:

To record the natural parasitism of *H. armigera*, initial instars of the gram caterpillar were collected from the field and reared in the laboratory in separate plastic containers (6.5 cm mouth diameter and 7 cm depth) to avoid the cannibalism. Food

was changed daily until a fortnight and observations were taken regularly. Record of parasitization was made and the percent parasitization calculated using the following formula:

$$\text{Parasitization (\%)} = \frac{\text{No: s of parasitized larvae}}{\text{Total larvae}} \times 100$$

3.4.3 Bio-efficacy:

3.4.3.1 Lay out of experiment:

To test the bioefficacy of a few bio-pesticides against the pest, the experiment was laid out in a randomized block design. Gram (variety - Dahod Yellow) was sown in plots of 5m x 5m maintaining a row-to-row distance of 30 cm and plant-to-plant distance of 10 cm. Other recommended agronomical practices such as, thinning, hoeing, weeding etc. were carried out as per schedule. The treatments comprised seven bio-pesticides *viz.*,

1. *Neem* oil (2%)
2. *Karanj* oil (2%)
3. *Neem* seed kernel extract (10%)
4. *Metarrhizium anisopliae* (oil formulation)
   (5×10^{12} conidia, Diesel: Sunflower as 7:3)
5. *M. anisopliae* (aqueous formulation)
   (5×10^{12} conidia in water, 0.1% Tween 80)
6. *M. anisopliae* (water emulsion)
   (5×10^{12} conidia, Emeleo R_2: Water, 1:99)
7. Bacterial preparation (*Pseudomonas aeruginosa*)
8. An untreated control

The bio-pesticide *M. anisopliae* oil formulation was sprayed using a ULV sprayer and the other bio-pesticides were sprayed using a calibrated knapsack sprayer. Observations on the larval population of the pod borer were taken one day before the treatment and at 1, 5 and 7 days after treatment.

3.4.3.2 Statistical analysis:

Efficacy of different treatments in controlling the pest was analyzed by analysis of variance. The pre-treatment and post-treatment data were corrected and converted to percent values using the method described by Henderson and Tilton (1955) as under:

$$\text{Per cent reduction in population} = 100 \times \left(1 - \frac{T_a \times C_b}{T_b \times C_a}\right)$$

Where,

Ta = Number of larvae after spraying in the treatments.

T_b = Number of larvae before spraying in the treatments.

C_a = Number of larvae in untreated check after spraying.

C_b = Number of larvae in untreated check before spraying.

The percent reduction values were transformed into arc sine values and subjected to analysis of variance.

Table 3.1 Mean weekly meteorological data during Oct. 2005 to March 2006

Std. week No.	Date	Temperature (°C)			R.H. (%)			Total rainfall of week (mm)
		Max.	Min.	Mean	Max.	Min.	Mean	
40	1-7 Oct., 2005	32.9	17.8	25.35	82	35	58.5	0.0
41	8-14 Oct.	33.6	16.8	25.20	80	31	55.5	0.0
42	15-21Oct.	32.8	16.1	24.45	82	25	53.5	0.0
43	22-28 Oct.	31.2	13.3	22.25	80	33	56.5	0.0
44	29-4 Nov.	31.0	12.7	21.85	82	28	55.0	0.0
45	5-11 Nov.	29.2	12.0	20.6	82	31	56.0	0.0
46	12-18 Nov.	30.3	11.7	21.0	81	27	54.0	0.0
47	19-25 Nov.	30.7	11.2	20.95	85	30	57.5	0.0
48	26-2 Dec.	27.2	9.3	18.25	76	28	52.0	0.0
49	3-9 Dec.	26.3	7.3	16.80	83	32	57.5	0.0
50	10-16 Dec.	25.1	5.9	15.50	83	30	56.5	0.0
51	17-23 Dec.	23.6	6.7	15.15	91	31	61.0	0.0
52	24-31 Dec.	24.1	5.8	14.95	91	30	60.5	0.0
01	1-7 Jan., 2006	23.0	7.0	15.0	77	37	57.0	0.0
02	8-14 Jan.	26.3	6.6	16.45	90	32	61.0	0.0
03	15-21 Jan.	28.0	10.0	19.0	79	20	49.5	0.0
04	22-28 Jan.	24.4	5.8	15.1	82	27	54.5	0.0
05	29-4 Feb.	29.5	9.6	19.55	85	27	56.0	0.0
06	5-11 Feb.	30.1	10.1	20.1	79	29	54.0	0.0
07	12-18 Feb.	31.5	13.2	22.35	75	28	51.5	0.0
08	19-25 Feb.	34.2	13.1	23.65	78	24	51.0	0.0
09	26-4 March	32.6	14.0	23.3	67	25	46.0	0.0
10	5-11March	30.4	13.2	21.8	72	32	52.0	5.7
11	12-18 March	28.8	14.6	21.7	75	30	52.5	0.0
12	19-25 March	33.4	16.2	24.8	53	17	35.0	0.0
13	26-1 April	32.5	14.5	23.5	43	16	29.5	0.0

4. RESULTS

The experimental findings on different aspects of the present investigation have been described in the following pages:

4.1 POPULATION DYNAMICS:

During *rabi* 2005-06, the incidence of *H. armigera* began in the fourth week of October *i.e.*, 43rd standard week (0.75 larvae/meter-row), the mean temperature and relative humidity during the period were 22.25°C and 56.5 per cent, respectively. The population increased and reached a peak (2.75 larvae/meter-row) in the third week of November (46th standard week) when the mean temperature and relative humidity were 21.0°C and 54 per cent, respectively. Later, the population declined and reached as low as 0.50 larvae/ meter-row during the last week of November (48th standard week).

The gram caterpillar population happened to reappear in the last week of December *i.e.*, 52nd standard week (0.50 larvae/meter row) when the mean temperature and relative humidity were 14.95°C and 60.5 per cent, respectively. The population of the gram caterpillar increased rapidly and reached to a peak of 5 larvae per meter-row in the first week of February (6th standard week) when the mean temperature and relative humidity were 20.1°C and 54.0 per cent, respectively; thereafter, the population declined and reached to 2 larvae/meter-row in the third week of February (8th standard week).

The larval population of *H. armigera* had a positive correlation with maximum temperature (r = +0.1878), minimum temperature (r = +0.0312) and mean temperature (r = +0.1179), but had a negative correlation with morning relative humidity (r = -0.1551), evening relative humidity (r = -0.3654) and mean relative humidity (r = -0.3281). However, the correlation coefficients were not significant (Table 2).

4.2 NATURAL PARASITIZATION OF *H. armigera*:

The field-collected larvae were reared in separate containers in the laboratory and were observed for the emergence of the natural parasitoids.

Parasitization started during 45th standard week (5-11 November). The maximum parasitization (24%) was due to the larval parasitoid identified as *Campoletis chloridae* Uchida (Hymenoptera: Ichneumonidae) that was recorded in the last week of November (48th standard week), when the mean temperature and relative humidity were 18.25°C and 52.0 per cent, respectively. During the month of January the field-collected larvae showed some mortality when reared in the laboratory. The mortality was probably due to some bacterial diseases (unidentified) as no parasite was found to emerge. In February 2006, the gram caterpillars were parasitized by a dipteran parasite and the parasitization was up to 20 per cent, which was due to the parasitoid identified as *Carcelia illota* (Diptera: Tachinidae). The mean temperature and relative humidity ranged between 19.55-22.35°C and 51.5-56.0 per cent, respectively, during that period (Table 3 & Plate-3).

4.3 BIO-EFFICACY OF BIO-PESTICIDES:

The data recorded on per cent reduction of pod borer population at 1, 5 and 7 days after treatment have been presented in Table 4. It was notable that all the treatments at all the intervals were better than the control in reducing the pod borer population.

1st day after treatment:

Application of *karanj* oil (2%) gave the best result and the population reduction was 27.84 per cent followed by oil formulation of *M. anisopliae* (25.24%), *Neem* oil at 2 per cent (19.32%) and aqueous formulation of *M. anisopliae* (18.51%). All these treatments were superior to the water emulsion of *M. anisopliae* in which 13.60 per cent population reduction was observed. The bacterial preparation of *Pseudomonas aeruginosa* was effective and resulted into 11.61 per cent reduction in the population of *H. armigera*. NSKE (*neem* seed kernel extract) spray at 10 per cent was least effective (11.24% population reduction).

5th day after treatment:

After fifth day of treatment oil formulation of *M. anisopliae* performed the best and the population reduction was 54.84 per cent. Aqueous formulation of *M.*

anisopliae showed 49.96 per cent population reduction followed by water emulsion spray of *M. anisopliae* (41% population reduction), bacterial preparation of *Pseudomonas aeruginosa* (38.23% population reduction), *neem* oil at 2 per cent (33.23% population reduction) However, karanj oil at 2 per cent (23.08% population reduction) and NSKE spray at 10 per cent were least effective (23.08% population reduction).

7th day after treatment:

Seven days after treatment the results again depicted the same trend as that was observed 5 days after spray. Highest population reduction was recorded for oil formulation of *M. anisopliae* (66.74%). Aqueous formulation of *M. anisopliae* was also effective (57.01%) in reducing the pest population followed by water emulsion of *M. anisopliae* (47.47%), *karanj* oil 2 per cent (46.07%), bacterial preparation of *Pseudomonas aeruginosa* (41.94%), *neem* oil 2 per cent (40.36%); whereas, NSKE at 10 per cent was least effective (32.68%) in reducing the pest population.

Note: The cost/ benefit ratio was not worked out because the bio-agents *viz.*, *M. anisopliae* was provided by the NCL (National Chemical Laboratory), Pune (Maharashtra) and *Pseudomonas aeruginosa* by Dr. H. N. Gour, Professor and Head, Department of Plant Pathology, Rajasthan College of Agriculture, Udaipur; besides, these two microbial agents were not available in the market, hence the market cost of these bio-agents was not known.

5. DISCUSSION

5.1 POPULATION DYNAMICS:

A critical study of the population dynamics of the gram caterpillar during *rabi* 2005-06 revealed that the population build up of the first flush of the pest began in the fourth week of October 2005 and peaked in the third week of November 2005. The second flush was recorded to begin in the last week of December 2005 and the population peaked for the second time in the first week of February 2006. Abiotic factors had a minor influence in regulating the population of *H. armigera*, as the correlations worked out were not significant. The severity of damage however depended on the population of the late instar larvae at pod formation stage.

Singh and Singh (1978) observed that temperature and relative humidity in the preceding period had a stronger influence on the pest incidence. Patel (1979) observed that high humidity ranging from 60-75 per cent and temperature ranging from 10 to 15°C during January might be critical factor for the multiplication of *H. armigera*. On the basis of six-year data, Vaishampayan and Veda (1980) suggested that a minimum daily temperature of 10 to 15°C and relative humidity 50 to 70 per cent could be conducive for the activity of the larval population of *H. armigera*. They were of the opinion that relative humidity below 75 per cent during the major active period from December to February should be considered as an indication of high population build up of *H. armigera* in gram.

Similar to our findings, Dakwale and Singh (1980) also recorded the incidence of *H. armigera* to began in January and reach to a peak in February. Kushwaha (1983) also reported that in southern Rajasthan *H. armigera* appeared on gram crop in January and continued infestation till the end of February. Almost similar results were obtained by Mehta *et al.* (1985) stating that an average low temperature of 15±3°C and relative humidity of 75±10 per cent during January and February were responsible for the continued build up of the pest population. However, Tripathy and

Sharma (1985) observed that a temperature range of 12 to 21°C and relative humidity below 70 per cent with low rainfall could be important factors for the population build up of *H. armigera.*

Many other workers have also reported that the gram caterpillar infestation was high during December to February (Yadav *et al.,* 1986, Ravi and Verma, 1997, Patel and Koshiya, 1997, etc.). Rao *et al*. (2001) noticed that pest incidence appeared 38 days after sowing. The peak incidence was recorded on 87-day-old crop during the month of January. Krishna *et al.* (2004) observed that number of trap catches of *H. armigera* increased with the advancement of crop stage and increase in temperature. They also reported that flowering and pod maturation stages of the crop coincided with the increase in moth population.

5.2 NATURAL PARASITIZATION:

A study on natural parasitization of *H. armigera* showed that parasitization started during November and was the maximum (24%) in the last week of November. The larval parasitiod was identified as *Campoletis chloridae* Uchida. In December-January the mortality was recorded due to some bacterial disease (Unidentified). In February the gram caterpillar parasitization ranged from 12-20 per cent and the parasitoid was identified as *Carcelia illota* Curran.

Earlier reports of Bilapate (1981) indicated the larval parasite (*Campoletis chloridae*) and pupal parasite (*Carcelia* sp.) as the most important natural enemies of *H. armigera*. Nikam and Gaikwad (1989) also reported that of the 100 species of parasitoids parasitizing *H. armigera,*among these *Campoletis chloridae* Uchida was predominant. Kushwaha (1989) reported *Banchopsis, Campoletis, Eriborus, Enicospilus, Palexorista, Carcelia* and *Goniphthalmus* to be more important among the larval/pupal parasitoids of *H. armigera* in India. Pawar *et al*. (1989) recorded the average parasitism of 1st to 3rd instar larvae of *H. armigera* by *C. chloridae* on chickpea to be 33.1 per cent. Rao *et al.* (1994) observed 4-10 per cent parasitization of larvae of *H. armigera* by the larval parasitoid, *C. chloridae.* Romeis and Shanower (1996) also reported that the larval parasitoid, *Campoletis chloridae* Uchida might parasitize more than 30 per cent of *H. armigera* larvae in chickpea. Kaur *et al.* (2000) observed parasitism due to *Campoletis chloridae* Uchida to range from 0.98 to 68.50 per cent throughout the crop season on different cultivars of chickpea.

5.3 BIOEFFICACY OF BIO-PESTICIDES:

The efficacy of different bio-pesticides against larvae of *H. armigera* under field conditions showed that the most effective bio-pesticide was oil formulation of *M. anisoipliae* (66.74% population reduction) followed by aqueous formulation of *M. anisopliae* (57.01% population reduction), water emulsion of *M. anisopliae* (47.47% population reduction), *Karanj* oil at 2 per cent (46.07% population reduction), *Pseudomonas aeruginosa* (41.94% population reduction) and *Neem* oil at 2 per cent (40.36% population reduction); whereas, NSKE at 10 per cent was least effective with 32.68 per cent population reduction.

Hongo and Karel (1986) observed that aqueous extracts from *Neem* seed kernels caused deterrent effect and antifeedent effect against *H. armigera*. Gupta *et al.* (1990) reported that *Neem* oil and *Karanj* oil, both treatment significantly reduced the larval population of *H. armigera*. Sachan and Lal (1993) also reported that all the treatments (*Neem* seed kernel extract, *Neem* leaf extract, *Neem* oil and other insecticides) reduced the pest population in chickpea. Sinha (1993) observed that *Neem* oil and NSKE 5% sprayed at an interval of 10 days gave a 2-fold reduction in population of *H. armigera.* Bajpai and Sehgal (1999) also reported that *Neem* oil at 2.0%, NSKE at 5.0 per cent and *Karanj* oil at 2 per cent were effective against the pest compared to control. Kulat *et al*. (2001) observed that the chickpea crop treated with the leaf extract of tobacco and seed extract of *Pongamia pinnata* (5%) and NSKE (5%) exhibited low level of the pest population built up compared to control.

Gopala Krishnan and Narayanan (1989) observed that treatment of *H. armigera* with *M. anisopliae* (1.8×10^9 conidia/ml) caused 80-100 per cent mortality of larvae in all 5 instars, pre pupae and pupae within 2-10 days. Burdeos and Villacarlos (1988) reported that all the fungi (*M. anisopliae, Paecilomyces lilacinus* and *Beauveria bassiana*) pathogenic to the insect (*Cylas formicarius*) at different degrees. Pandit and Samanta (1995) also concluded that mortality of the pest (*Spilosoma obliqua*) was 75-91 per cent due to *M. anisopliae.* Gardezi and Mahmood (1998) reported that, nine species of fungi including *M. anisopliae* were infectious to

Chilo partellus. Sridevi *et al*. (2004) recorded that *Beauveria bassiana* (1.6 x10^5 to 2.5 x 10^5 spore/ml) resulted in 60.4-75.3 per cent larval mortality of *H. armigera.*

Odak *et al*. (1982) reported that Bactospeine and Thuricide were highly pathogenic to larvae of *H. armigera* causing 20-65 per cent mortality in the pot experiment. Prasad and Kushwaha (1990) observed that the larvae of *Spodoptera litura* (Fab) were found to be infected with *Pseudomonas aeruginosa*, *Streptococcus* sp., *M. anisopliae* and *Entomophthora* sp. Broza and Sneh (1994) recorded that application of *B. thuringiensis* suppressed the population of *H. armigera*. Schneider and Dorn (2001) concluded that *Pseudomonas aeruginosa* killed all the test insects within 48 hours. Pharindera Yadav *et al.* (2004) recorded lowest number of larvae in treatment with Delfin.

6. SUMMARY

The present investigation, "Bio-ecological studies on pod borer [*Helicoverpa armigera* (Hubner) Hardwick] and its management through bio-pesticides in chickpea" was carried out at Agronomy farm, Rajasthan College of Agriculture, Udaipur during *rabi* 2005-06.

The gram pod borer, *H. armigera* incidence initiated in the fourth week of October 2005 and touched the peak in the third week of November 2005 (2.75 larvae/meter row). The pest population happened to reappear in the last week of December 2005 *i.e.*, 52nd standard week; thereafter, it increased rapidly and reached to a peak of 5.0 larvae per meter row in the first week of February 2006. The abiotic factors of the environment did not have a significant influence on the pest population.

Observation on natural parasitization showed that parasitization was the maximum in the last week of November (24%) due to the larval parasitoid, *Campoletis chloridae* Uchida (Hymenoptera: Ichneumonidae); whereas in February the gram caterpillar parasitization was 20 per cent due to the parasitoid, *Carcelia illota* Curran (Diptera: Tachinidae).

The efficacy of various bio-pesticides against the larvae of *H. armigera* under field conditions showed that the most effective bio-pesticide was oil formulation of *M. anisopliae* which caused 66.74 per cent reduction in the larval population followed by aqueous formulation of *M. anisopliae* (57.01%), water emulsion of *M. anisopliae* (47.47%), *karanj* oil at 2 per cent (46.07%), bacterial preparation of *Pseudomonas aeruginosa* (41.94%), *neem* oil at 2 per cent (40.36%) and NSKE at 10 per cent (32.68%).

Table 2. Population dynamics of *Helicoverpa armigera* in chickpea during *rabi* 2005-06

Standard weather week	Average Temperature (°C)			Average Relative humidity (%)			Larval population per meter row
	Maximum	Minimum	Mean	Morning	Evening	Mean	
40	32.9	17.8	25.35	82	35	58.5	0.00
41	33.6	16.8	25.20	80	31	55.5	0.00
42	32.8	16.1	24.45	82	25	53.5	0.00
43	31.2	13.3	22.25	80	33	56.5	0.75
44	31.0	12.7	21.85	82	28	55.0	1.50
45	29.2	12.0	20.6	82	31	56.5	2.00
46	30.3	11.7	21.0	81	27	54.0	2.75
47	30.7	11.2	20.95	85	30	57.5	1.00
48	27.2	9.3	18.25	76	28	52.0	0.50
49	26.3	7.3	16.80	83	32	57.5	0
50	25.1	5.9	15.50	83	30	56.5	0
51	23.6	6.7	15.15	91	31	61.0	0
52	24.1	5.8	14.95	91	30	60.5	0.50
01	23.0	7.0	15.0	77	37	57.0	1.25
02	26.3	6.6	16.45	90	32	61.0	2.00
03	28.0	10.0	19.0	79	20	49.5	2.75
04	24.4	5.8	15.1	82	27	54.5	3.50
05	29.5	9.6	19.55	85	27	56.0	4.50
06	30.1	10.1	20.1	79	29	54.0	5.00
07	31.5	13.2	22.35	75	28	51.5	3.50
08	34.2	13.1	23.65	78	24	51.0	2.00
	r = 0.1878	r = 0.0312	r = 0.1179	r = -0.1551	r = -0.3654	r = -0.3281	

r = Correlation coefficient

Table 3. Natural parasitization of *H. armigera* in chickpea during *rabi* 2005-06

Std. week No.	Avg. mean temperature (°C)	Avg. mean Relative humidity (%)	Total number of larvae observed	Number of parasitized larvae recorded	% parasi-tization	*Parasite*
45	20.6	56.5	25	02	8	*Campoletis chloridae* Uchida
46	21.0	54.0	25	04	16	
47	20.95	57.5	25	03	12	
48	18.25	52.0	25	06	24	
49	16.80	57.5	-	-	-	No larvae could be collected from the fields
50	15.50	56.5	-	-	-	
51	15.15	61.0	-	-	-	
52	14.95	60.5	25	-	-	Mortality due to bacterial diseases
01	15.0	57.0	25	-	-	
02	16.45	61.0	25	-	-	
03	19.0	49.5	25	-	-	
04	15.1	54.5	25	-	-	

05	19.55	56.0	25	05	20	*Carcelia illota* Curran
06	20.1	54.0	25	04	16	
07	22.35	51.5	25	03	12	

Table 4. Bioefficacy of bio-pesticides against *H. armigera* in chickpea during *rabi* 2005-06

S. No.	Treatments	Reduction in population (%)		
		1 DAS	***5 DAS***	***7 DAS***
1.	Neem oil (2%)	26.07 (19.32)	35.20 (33.23)	39.44 (40.36)

2.	NSKE (10%)	19.58 (11.24)	28.71 (23.08)	34.87 (32.68)
3.	Karanj oil (2%)	31.85 (27.84)	28.71 (23.08)	42.75 (46.07)
4.	*M. anisopliae* (aqueous formulation)	25.48 (18.51)	44.98 (49.96)	49.03 (57.01)
5.	*M. anisopliae* (oil formulation)	30.16 (25.24)	47.78 (54.84)	54.78 (66.74)
6.	**M. anisopliae *(water emulsion)***	21.64 (13.60)	39.81 (41.0)	43.55 (47.47)
7.	*Pseudomonas aeruginosa*	19.92 (11.61)	38.19 (38.23)	40.36 (41.94)
SEm±		6.98	6.15	3.96
C.D. (P = 0.05)		NS	NS	11.76*

Note:

- Figures in parentheses are retransformed angular per cent values over control.
- * = Significant

LITERATURE CITED

Anonymous.1988b. Final progress Report(1984-87). ICAR scheme on determination of economic threshold level and off season bio-ecology of important insect pest of pulses.Department of Entomology,RCA, Udaipur(India),pp.30-32.

Anonymous.1992a. Achievement, Silver Jubilee 1967-1992. All Indian Coordinated Research project on Cotton, Nagpur, Maharastra, India. Central Institute for Cotton Research. pp.117-151.

Anonymous.2004. Vital Agriculture statistics.Statistical Cell, Directorate of Agriculture, Government of Rajasthan, Jaipur(Raj.).

Anonymous.2005.Economic Survey 2004-05. Ministry of Finance and Company Affairs, Government of India.

Babu, P.C.S. and Rajasekaran, B. 1984. Evaluation of certain synthetic pyrethroids and vegetable products for the control of bengal gram pod borer, *Heliothis armigera* (Hubner). *Pesticides*, **18**(10):58-59.

Bajpai, N.K. and Sehgal, V.K. 1999. Field efficacy of *neem*, karanj and tobacco formulations against *Helicoverpa armigera* (Hubner) on chickpea crop at Pantnagar. *Journal of Insect Science,* **12**(1): 92-94.

Bajpai, N.K. and Sehgal, V.K. 2003. Effect of botanicals on oviposition behaviour of *Helicoverpa armigera* moths at Pantnagar, India. *Indian Journal of Entomology*, **65**(4): 427-433.

Banerjee, A. and Dangar, T.K. 1995. *Pseudomonas aeruginosa,* a facultative pathogen of red palm weevil, *Rhynchophorus ferrugineus. World Journal of Microbiology and Biotechnology,* **11**(6): 618-620.

Bhatnagar, V.S. and Davies, J.C. 1978. Factor affecting population of gram pod borer, *Heliothis armigera* (Hubner) at Patancheru (A.P.). *Bulletin of Entomology,* **19**: 52-64.

Bhatt, N.J. and Patel, R.K. 2001. Biology of Chickpea pod borer, *H. armigera*. *Indian Journal of Entomology,* **63**(3): 225-259.

Bilapate, G.G. 1981. Investigation of *Heliothis armigera* (Hubner) in Marathwada. XXIII. Key mortality factors on cotton, pigeonpea and chickpea. *Proceeding of the Indian Academy of Science,* **47 B**: 637-666.

Borah, R.K. 1998. Influence of sowing dates on the infestation of *Helicoverpa armigera* and grain yield of chickpea in the hill zone of Assam. *Indian Journal of Entomology*, **59**(4): 416.

Broza, M. and Sneh, B. 1994. *Bacillus thuringiensis* sp. *kurstaki* as an effective control agent of Lepidopteran pests in tomato fields in Israel. *Journal of Economic Entomology*, Lanham., **87**(4): 923-928.

Burdeos, A.T. and Villacarlos, L.T. 1988. Pathogenicity of three entomogenous fungi to adult sweet potato weevil, *Cylas formicarius* (F.). Cebu City (Philippines), 1p.

Chakraborti, S. and Chatterjee, M.L. 1999. Bio-efficacy of Azadirachtin and other *neem* pesticides against the pod borer, *Helicoverpa armigera* Hubn. on chickpea. *Journal of Applied Zoological Researches,* **10**(2): 118-112.

Dakwale, R.N. and Singh, R. 1980. Logistic growth curve in *Heliothis armigera* (Hub.) population. *Geobios,* **7**(2): 57-60.

Derek, A. and Russell. 1999. Insecticides resistance and its management in *Helicoverpa armigera* (Lepidoptera: Noctuidae) in India. *Indian Journal of Plant Protection*, **27**(1&2): 32-46.

Ferron, P., Robert, P.H. and Deotte, A. 1975. Susceptibility of *Oryctes rhinoceros* adults to *Metarrhizium anisopliae. Journal of Invertebrate Pathology,* **25**(3): 313-319.

Gallego, B.C. and Gallego, C.E. 1989. Efficacy of *Beauveria bassiana* Vuill. and *Metarrhizium anisopliae* Mets. and Sor. against three coconut pests. *Tirathaba rufivena, Promecotheca cumingii and Plesispa reichei.* Baguio City (Philippines), 1 leaflet.

Gardezi, S.R.A. and Mahmood, K. 1998. Some entomogenous fungi, infectious to maize stem borer. *Sarhad Journal of Agriculture* (Pakistan), **14**(3): 249-252.

Gopala Krishnan, C. and Narayan, K. 1990. Studies on the dose mortality relationship between the entomofungal pathogen, *Beauveria bassiana* (Bals.) Vuillemin and *Heliothis armigera* Hubner (Lepidoptera : Noctuidae). *Journal of Biological Control,* **4**(2): 112-115.

Gopala Krishnan, C. and Narayanan, K. 1989. Studies on the susceptibility of *Heliothis armigera* Hubner (Lepidoptera: Noctuidae) to the entomopathogenic fungus, *Metarrhizium anisopliae* (Metschnikoff) Sorokin var. *anisopliae. Tulloch. Entomon*., **14**(3-4): 191-197.

Gupta, M.P., Parsai, S.K. and Gupta, D.P. 1990. Bioefficacy and economics of certain insecticides and vegetable oils against gram pod borer, *Heliothis armigera* Hubner on chickpea. *Indian Journal of Plant Protection,* **18**(2): 207-211.

Henderson, C.F. and Tilton, E.W. 1995. Tests with acaricides against the brown wheat mite. *Journal of Economic Entomology*, **48**(2):157-161.

Hongo, H and Karel, A.K. 1986. Effect of plant extract on insect pest of common beans. *Journal of Applied Entomology*, **102**(2): 164-169.

Inglis, G.D., Lawrence, A.M. and Davis, F.M. 2000. Pathogens associated with south western corn borers and southern corn stalk bores (Lepidoptera : Crambidae). *Journal of Economic Entomology*, **93**(6): 1619-1626.

Jaglan, M.S., Khokhar, K.S., Malik, M.S. and Singh R. 1997. Evaluation of *neem* (*Azadirachta indica* A. Juss.) extracts against American bollworm, *Helicoverpa armigera* (Hubner). *Journal of Agriculture and Food Chemistry*, **45**(8): 3262-3268.

Kaur, S., Brar, K.S. and Shehnmar, M. 2004. Effect of different chickpea cultivars on parasitization of *Helicoverpa armigera* (Hubner) by *Campoletis chloridae* Uchida. *Journal of Biological Control,* **18**(1): 69-72.

Kaur, S., Brar, K.S., Sekhon, B.S., Joshi, N., Shenhmar, M. and Singh, J. 2000. Role played by *Compoletis chloridae* Uchida in natural mortality of *Helicoverpa armigera* (Hubner) on chickpea in Punjab. *Journal of Biological Control,* **14**(1): 51-54.

Kaushik, S.K. and Naresh, J.S. 198. Population dynamics, distribution pattern and damage of *H. armigera* on chickpea. *Indian Journal of Entomology,* **54**(4): 225-228.

Khalique, F., Ahmed, K. and Afzal, M. 1989. Evaluation of *Bacillus thuringiensis* Berliner against chickpea pod borer. *Pakistan Journal of Scientific and Industrial Research,* **32**(2): 114-116.

Krishna, K., Kanaujia, K.R. and Kanaujia, S. 2004. Population assessment of *Helicoverpa armigera* moth through sex pheromone trap. *Annals of Plant Protection Sciences,* **12**(2): 431-432.

Kudale, R.A., Patil, B.D., Bhagvati, V.Y. and Choudhari, C.S. 2002. Field efficacy of certain ready mix formulation of insecticides against the pod borer (*Helicoverpa armigera* Hub.) on chickpea. *Pestology*, **26**(8): 32-34.

Kulat, S.S., Nandanwar, V.N., Zade, N.N. and Tirthkar, S.S. 2001. Evaluation of some indigenous plant products for the management of *Helicoverpa armigera* Hubn. on chickpea. *Journal of Applied Zoological Researches,* **12(**2-3): 96-98.

Kulkarni, K.A. , Kambrekar, D.N. and Gundannavar, K.P.2005. Management of *Helicoverpa armigera* Hubner on Chickpea through biopesticide . *Karnataka Journal of Agricultural sciences,* **18**(4): 1114-1116

Kushwaha, K.S. 1983. Some practical recommendations depicting research highlights in pest management in Rajasthan. *Pesticides,* **17**(7): 5-146.

Kushwaha, K.S. 1989. The role of biological control in pest management in India, emphasizing *Heliothis* spp. pages 21-29 *In*: Proceeding of the Workshop on Biological Control of *Heliothis*: Increasing the Effectiveness of Natural Enemies, 11-15 November 1985, New Delhi, India.

Metho, D.N., Singh, K.M. and Singh, R.N. 1985. Incidence of insect pests in chickpea, *Cicer arietinum* (Linn.). *Indian Journal of Entomology,* **47**(2): 117-136.

Mortimore, B., Wingo, B. and Ducoff, H.S. 1971. X-irradiation and acquired immunity in larvae of *Tenebrio molitor*. Society for Invertebrate Pathology: IV International

Colloquium on Insect Pathology. With the society for Invertebrate Pathology. College Park, Maryland. USA, 25-28 August, 1970. 237-246.

Nikam, P.K. and Gaikwad, A.M. 1989. Role of hymenopterous parasitoids in the biological control of *Heliothis armigera* (Hub.) with special reference to *Campoletis chloridae* (Uchida) in India. *Journal of Entomological Research*, **13**(1-2): 6-20.

Odak, S.C. 1981. Seasonal history of gram pod borer, *Heliothis armigera* (Hub.). *In*: Annual Progress Report on Integrated Control of Gram Pod Borer, *Heliothis armigera* (Hub.), Department of Entomology, JNKVV, Jabalpur (M.P.): 4-8.

Odak, S.C., Shrivastava, D.K., Mishra, V.K. and Nema, K.K. 1982. Preliminary studies on the pathologenicity of *Bacillus thuringiensis* and nuclear polyhedrosis virus on *Heliothis armigera* host in the laboratory and in pot experiment. *Legume Research,* **5**(1): 13-17.

Osborn, F., Berlioz, L., Vitalli Flores, J., Monsalve, W., Dorta, B. and Lemoine, V.R. 2002. Pathogenic effects of bacteria isolated from larvae of *Hylesia metabus* Crammer (Lepidoptera: Saturniidae). *Journal of Invertebrate Pathology,* **80**(1): 7-12.

Pandit, N.C. and Samanta, B.K. 1995. Effect of biocides (*Beauveria bassiana* (Bals.) Vuill. and *Metarrhizium anisopliae* (Metsch.) Sorok. on the polyphagous insect pest (*Spilosoma obliqua* walker) of bast fiber crops. *Environment and Ecology*. **13**(2): 469-470.

Patel, C.C and Koshiya, D.J. 1999. Population dynamics of gram pod borer, *Helicoverpa armigera* (Hubner) Hardwick on cotton, pigeonpea and chickpea. *Gujarat Agricultural University Research Journal,* **24**(2): 62-67.

Patel, C.C. and Koshiya, D.J. 1997. Seasonal abundance of American bollworm, *Helicoverpa armigera* on different crop host at Junagarh (Gujarat). *Indian Journal of Entomology,* **59**(4): 396-401.

Patel, R.K. 1979. Unusual outbreak of gram pod borer on gram in Madhya Pradesh. *Science and Culture,* **45**: 335-336.

Pawar, C.S., Bhatnagar, V.S. and Jadhav, D.R. 1989. *Campoletis chloridae* Uchida (Hymenoptera : Icheumonidae) as a parasite of *Helicoverpa armigera* (Hub.) (Lepidoptera : Noctuidae) in southwest India. *Proceedings of the Indian Academy of Sciences,* **98**(4): 259-265.

Pharindera Yadav, Maghodia, A.B. and Vyas, R.V. 2004. Efficacy of microbial bioagents against *Helicovepa armigera* on chickpea. *International Chickpea and Pigeonpea News Letter,* 41-43.

Poprawski, T.J. and Yule, W.N. 1990. Bacterial pathogens of *Phyllophaga* spp. (Coleoptera : Scarabaeidae) in southern Quebec, Canada. *Journal of Applied Entomology,* **109**(4): 414-422.

Prado, E. 1980. Control of black vine weevil larvae (*Otiorhynchus sulcatus*) using the insect-pathogenic fungi *Beauveria bassiana, Metarrhizium anisopliae* and *Metarrhizium flavoviride. Vaxtskyddsnotiser.* **44**(6): 160-167.

Prasad, D., Chand, P. and Haque, M.F. 1987. Parasitization of *Heliothis armigera* (Hub.) in chickpea field as affected by pesticidal seed treatment. *Research and Development Reporter,* **4**(2): 236-238.

Prasad, D., Chand, P., Deka, N.K. and Prasad, R. 1989. Population dynamics of *Heliothis armigera* (Hub.) on chickpea. *Giornale Haliano-di- Entomologia,* **22**(4): 223-228.

Prasad, J. and Kushwaha, K.S. 1990. Role of pathogenic microbes in management of the tobacco caterpillar, *Spodoptera litura* (F.) in cabbage and cauliflower crops. *Indian Journal of Entomology,* **52**(4): 641-652.

Prasad, V.D., Jayaraj, S. and Rabindra, R.J. 1990. Susceptibility of gram caterpillar, *Heliothis armigera* Hbn. (Noctuidae: Lepidoptera) to certain entomogenous fungi. *Journal of Biological Control,* **4**(1): 44-47.

Rao, K.P., Sudhakar, K. and Krishnaiah, K.R. 2001. Seasonal incidence and host preference of *Helicoverpa armigera* (Hubner). *Indian Journal of Plant Protection,* **29**(1&2): 152-153.

Rao, R.S.N., Sreedhar, U., Rao, S.G. and Satyavani, J.V.R. 1994. Bio-environmental control of *Heliothis armigera* in FCV tobacco. *Tobacco Research,* **20**(1): 36-39.

Ravi, G. and Verma, S. 1997. Seasonal incidence of chickpea pod borer, *Helicoverpa armigera* and its larval parasitoid on chickpea crop. *Indian Journal of Entomology*, **59**(4): 359-361.

Reed, W. and Pawar, C.S. 1982. *Heliothis* : A global problem. *In*: Proceeding International Workshop on *Heliothis* Management. 15-20 November, 1981, ICRISAT India, pp. 9-14.

Romeis, J. and Shanower, T.G. 1996. Arthropod natural enemies of *Helicoverpa armigera* in India. *Biocontrol Science and Technology*, **6**: 481-508.

Rote, N.B. and Thakkar, S.P. 2001. Laboratory studies on bioefficacy of different biopesticides against *H. armigera* (Hub.). *Indian Journal of Applied Entomology*, **15**(2): 57-59.

Sachan, J.N. and Katti, Gururaj 1993. *Neem* in *Helicoverpa* (*Heliothis*) *armigera* management. Pulses ecosystem. Abstract, *World Neem Conference*, February, Bangalore, India P.459.

Sachan, J.N. and Lal, S.S. 1993. Role of botanical insecticides in *Helicoverpa armigera* management in pulses. *Botanical Pesticides in Integrated Pest Management*, 261-269.

Schneider, M. and Dorn, A. 2001. Differential infectivity of two *Pseudomonas* species and the immune response in the milkweed bug, *Oncopeltus fasciatus* (Insecta: Hemiptera). *Journal of Invertebrate Pathology*, **78**(3): 135-140.

Sehgal, V.K. and Ujagir, R. 1990. Effect of synthetic pyrethroids, *neem* extracts (from *Azadirachta indica* seed kernels) and other insecticides for the control of pod damage by *Helicoverpa armigera* (Hubner) on chickpea and pod damage-yield relationship at Pantnagar in northern India. *Crop Protection*, **9**(1): 29-32.

Shankar, G. Mallikarjunappa, Ganesh, S., Bhat, U., Borde, P.R. and Sivasankram, K. 1992. Evaluation of Biobit *Bacillus thuringiensis* var. *Kurstaki* against *Helicoverpa armigera* (Hub.) damaging pigeon pea. *Pestology*, **16**(9): 16.

Sharma, H.C. 2001. Cotton bollworm/Legume pod borer, *Helicoverpa armigera*: Biology and Management. Crop protection compendium. Walling Ford, UK: CAB International. 72 pp.

Sharma, S.S. and Dahiya, B. 1986. Efficacy of some plant oils against pod borer, *Heliothis armigera* (Hubner) on chickpea. *Neem Newsletter,* **3**(2): 15-17.

Sheikher, C. and Sharma, P.L. 1997. Toxic and morphogenic effects of *neem* leaf extracts on *Helicoverpa armigera* (Hubner). *Pest Management and Economic Zoology,* **5**(2): 95-100.

Singh, B. and Yadav, R.P.2005.Field efficacy of some microbial agents against *Helicoverpa armigera* Hub. on chickpea. Journal of Applied Zoological Researches, **16**(1) : 5-6

Singh, R.N. and Singh, K.M. 1978. Incidence of insect pests in early varieties of red gram, *Cajanus cajan* (L.) Millsp. *Indian Journal of Entomology,* **40**(3): 229-244.

Singh, R.P., Singh, Y. and Singh, S.P. 1985. Field evaluation of *neem* (*Azadirachta indica* A. Juss.) seed kernel extracts against the pod borer of pigeonpea, *Cajanus cajan* (L.). *Indian Journal of Entomology*, **47**(1): 111-112.

Sinha, S.N. 1993. Control of *Helicoverpa armigera* Hb. infesting chickpea : field efficacy of *neem* products and insect growth regulator. *Indian Journal of Plant Protection*, **21**(1): 80-84.

Sridevi, T., Krishnaya, P.V. and Rao, P.A. 2004. Efficacy of microbial alone and in combinations on larval mortality of *Helicoverpa armigera* (Hub.). *Annals of Plant Protection Sciences,* **12**(2): 234-247.

Srinivas, P.R. 1989. Extent of parasitism of gram pod borer (*Heliothis armigera*) by ichneumonid larval parasites. *Indian Journal of Agricultural Sciences*, **59**(6): 377-378.

Suganthy, M. 2000. Efficacy of different plant protection options on the oviposition preference of gram pod borer, *H. armigera* (Hub.) in chickpea. *Indian Journal of Plant Protection*, **28**(1): 61-63.

Thang, M.H. and Shepard, B.M. 1988. Effect of *Metarrhizium anisopliae* and *Beauveria bassiana* (Deuteromycotina) and buprofezin on the brown plant hopper, *Nilaparvata lugens* (Stal.) (Homoptera: Delphacidae), and the Wolf spider, *Lycosa pseudoannulata* Boes et strand (Araneae: Lycosidae). Cebu City (Philippines), 1p.

Tikar, S.N., Rao, N.G.V., Satpute, N.S. and Dandale, H.G. 2001. Egg laying preference and larval parasitization of *Helicoverpa armigera* (Hubner) on weed host *Lagascea mollis* (Cav.) in comparison with cotton at Akola. *Insect – Environment*, **6**(4): 180-181.

Tripathy, S.R. and Sharma, S.K. 1985. Population dynamics of *H. armigera* on gram in the Tarai belt of north-east Uttar Pradesh (India). *G. Ital. Entomol*., **2**(10): 347-354 (*c.f.*: RAE (A), 74(10): 538, 1986).

Vaishampayan, S.M. and Veda, O.P. 1980. Population dynamics of gram pod borer, *Helicoverpa armigera* (Hub.) and its outbreak situation on gram at Jabalpur. *Indian Journal of Entomology,* **42**(3): 453-457.

Verma, A. and Singh, K. 1987. New records of entomogenous bacteria infecting some insects pests of sugarcane in the state of Uttar Pradesh, India. *Entomology Newsletter,* **18**: 13-15.

Wanjari, R.R, More, G.D., Supare, N.R., Turkar, K.S. and Agarkar, V.K. 1998. Management of *Helicoverpa armigera* (Hub.) on chickpea with some herbal, chemical and bio-pesticides. *Journal of Soils and Crops,* **8**(1): 34-37.

Yadav, B.R., Trivedi, P.C. and Yadav, C.P.S. 2000. Biocontrol efficacy of entomogenous fungus, *Metarrhizium anisopliae* against white grub (*Holotrichia consanguinea* Blanch.). *Journal of Mycology and Plant Pathology,* **30**(3): 416-418.

Yadav, D.N., Patel, R.C. and Patel, D.S. 1986. Seasonal incidence of *Heliothis armigera* (Lepidoptera : Noctuidae) on different host plant at Anand (Gujarat). *Gujarat Agricultural University Research Journal,* **11**(2): 32-35.

Yadav, L.S. and Yadav, P.R. 1983. Insecticidal control of pod borer, *Heliothis armigera* on Kabuli gram. *Pesticides,* **27**(5): 25-26.