BEHAVIOURAL STUDIES OF *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) AND ITS MANAGEMENT IN CHICKPEA

By
LAKSHMIPATHI SRIGIRIRAJU

Thesis submitted to the Pondicherry University in partial fulfilment for the award of the degree of "Master of Science in Ecology".

Department of Ecology and Environmental Sciences,
Salim Ali School of Ecology
Pondicherry University
Pondicherry 605 014
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CERTIFICATE

This is to certify that the thesis entitled "**Behavioural studies of *Helicoverpa* (Hubner) (Lepidoptera: Noctuidae) and its management in chickpea**" submitted in partial fulfilment of the requirements for the degree of "Master of Science in Ecology" of the Pondicherry University, Pondicherry, is a record of the bonafide research work carried out by Mr. Lakshmipathi Srigiriraju under my guidance and supervision.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been duly acknowledged by the author of the thesis.

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DECLARATION

I, Mr. Lakshmipathi Srigiriraju hereby declare that the thesis entitled "**Behavioural studies of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and its management in chickpea**" submitted to the Pondicherry University for the degree of Master of Sciences in Ecology and Environmental Sciences is the result of the original work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

Date: 24-4-2000
Place: Pondicherry University,
Pondicherry

(Lakshmipathi Srigiriraju)

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Title of the thesis	: Behavioural studies of *Helicoverpa armigera* (Hubner) (Lepidoptera : Noctuidae) and its management in chickpea
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Abstract

The research activities entitled, " **Behavioural studies of *Helicoverpa armigera* (Hubner) (Lepidoptera : Noctuidae) and its management in chickpea** ",conducted during post-rainy season, 1999-2000, at International Crops research Institute for the Semi-arid Tropics, Patancheru location, Andhra Pradesh, India, indicated that, by the pheromone trap catches of *H.armigera* males, the peak moth activity was found to be between 0200 and 0400h. The environmental factors temperature, humidity and wind velocity appear to have a marked effect on the moth catch but were merely coincidental with the time of the night. The research conducted on the orientation and flight pattern towards the pheromone source in *H.armigera* suggests that it consists of several distinct stages with deviation from a straight upwind path taking place largely in the vertical plane, with different flight patterns.

The ovipositional preference of *H.armigera* to flower color variation in pigeonpea have shown a remarkable preference towards yellow colored flowers (83.3)to oviposit than to the red colored flowers (36) in the choice tests. Though the female laid less number of eggs (56.4) on the red color flowers than yellow (64) in no-choice tests, the differences were not significantly different.

All the treatments that were tested against *H.armigera* were found to be significantly superior to the unsprayed plots, in managing the larval population of the pest. The effectiveness of various treatments on *H.armigera* were in the order of Endosulfan (37 percent reduction over control) followed by IPM (30), NPV (27), Annona (28), Neem (22) and erecting bird perches (21).

Endosulfan registered the lest percentage pod damage (20.5), followed by IPM (22.6) as against the highest percentage pod damage in control (40.7). A maximum yield of 13.9 q ha $^{-1}$was obtained with endosulfan, but was on par with IPM (13.6 q ha $^{-1}$) as against 8.5 q ha^{-1} in the control plots. IPM was adjudged as the most profitable way to manage the pest, with little inputs on pesticides, which recorded a cost-benefit ratio of 1:9 followed by endosulfan treatment (1:8.7).

The studies on the fluctuation of *H.armigera* pest population revealed that the larval population attained two major peaks, at 68 and 90 days of crop age, which coincided with peak flowering and podding stages of the crop respectively.

List of abbreviations

%	=	per cent
@	=	at the rate of
cm	=	centimeter
DAS	=	days after sowing
DAT	=	days after treatment
EC	=	emulsifiable concentrate
et al	=	and others
Fig	=	figure
g	=	gram
ha	=	hectare
i..e.	=	that is
IPM	=	Integrated Pest Management
Kg ha^{-1}	=	kilogram per hectare
kg	=	kilogram
LE ha^{-1}	=	Larval Equivalents per hectare
LSD	=	Least significant difference
m	=	meter
m^2	=	meter square
mm	=	millimeter
NPV	=	Nuclear Polyhedrosis Virus
^{o}C	=	degree centigrade
PPM	=	Parts per million
q ha^{-1}	=	quintals per hectare
spp.	=	species
viz.,	=	namely

INTRODUCTION

Chapter I

Introduction

Pulses form an integral part of the vegetarian diet in the Indian sub-continent. Besides being a very rich source of protein, they maintain soil fertility through biological nitrogen fixation by bacteria prevalent in their root nodules, thus play a vital role in 'sustainable agriculture'.

Among various pulse crops chickpea (*Cicer arietinum* L.) and Pigeonpea (*Cajanus cajan* (L) Millspaugh) are important in different production systems of semi-arid tropical nations. Of the 11 m ha of chickpea and 4 m ha of Pigeonpea grown worldwide, about 75% of chickpea and 90% of Pigeonpea are grown in south Asia. India is the world's leading producer of chickpea and Pigeonpea with 68% and 95% of the total production. But the current productivity levels of pulses is low, 200-700 kg ha^{-1}. Biotic stresses are known to be the primary yield reducers in pulse production. Among various biotic constraints, insect pests are regarded as the key factor. About 200 species of insects are known to attack the pigeonpeas of which *Helicoverpa armigera* is the number one. Relatively few insect pests attack chickpea compared to Pigeonpea. This is probably because it is a cool -season crop and also because of the acidic substances produced by dense glandular trichomes, which deter most of the insects. However, *Helicoverpa* is a dominant pest in chickpea crop. Annual losses due to *H.armigera* in chickpea and pigeon pea alone have recently been estimated to exceed US $600 million (International crops research Institute for the semi-arid tropics, 1992). Losses in other crops add substantially to the total damage caused by *H.armigera.*

The biological characteristics such as high degree of polyphagy, high mobility, facultative diapause, high fecundity and multigeneration (Fitt, 1989) contribute directly to the pest status of *Helicoverpa.*

Plant protection in India and in most of the developing countries is mainly based on the use of chemical pesticides. Chemical control is one of the effective and quicker methods in reducing pest population, where farmers obtain spectacular results within a short period. However, over-reliance and indiscriminate use of pesticides for a longer periods resulted in a series of problems in the Agro-Ecosystems, mainly, the development of resistance in the insects to the pesticides, resurgence of the treated population, outbreak of the secondary pests into primary status, destruction of natural enemies, increase in inputs on chemicals, environmental pollution and toxicological hazards due to pesticide residues, etc., All these problems forced to develop alternative options to chemicals and integrate them. This is based on the principles of managing the pest rather than aiming at complete eradication. This Integrated Pest Management (**IPM**) approach will ultimately reduce the negative influence of insecticides on the natural enemies, that are present in the suitable ecological niche and will protect the ecosystem and the environment from toxicological hazards.

Effective monitoring is the prerequisite for developing any pest management strategy. In recent years synthetic pheromones were developed for key pests. Pheromone traps, which are used for monitoring of adult insects, rely upon a sexually mediated response for their effective attraction and capture of males. The time and size of the catches during the night may reflect the extent of the natural mating activity. The environmental factors, like, temperature, relative humidity and wind velocity may play critical role in their activity.

A good understanding of the male moth behavior is of importance to increase the efficiency of the trapping procedures. The understanding of insect orientation towards a pheromone source is also an intrinsically important study. To strengthen existing plant protection and to develop IPM packages the understanding of insect behavior plays a critical role. Though the adult moths of *H.armigera* do not cause any direct injury to the plants, they cause serious problems by spreading their progeny in large areas. The basic knowledge and understanding about the oviposition behaviour of *H.armigera* is of great importance in pest management.

The complete chain of behavioural sequences which culminate in oviposition, is guided by multiple sensory cues (Miller and Strickler, 1984), like olfactory and visual, particularly, color (Isle, 1937; Prokopy and Owens, 1983).

Considering the importance of adult behavior of *Helicoverpa* in developing IPM technologies the present study has been undertaken with the following objectives.

1. ***To understand the flight pattern and peak moth activity of adult H.armigera.***

2. ***To understand the oviposition preference of Helicoverpa female moth, and***

3. ***To develop Integrated pest management strategies against Helicoverpa armigera on chickpea.***

REVIEW OF LITERATURE

Chapter II

Review of Literature

The literature that was available, concerning the present studies is categorized under different heads and presented in this chapter.

2.1 Moth Activity and flight pattern:

Activity characterized by a partial physiological or behavioural state of the insect that makes it more susceptible to capture has been referred to as an "**Insect Phase Effect**" by Southwood, 1978.

Taylor, 1963 while conducting experiments on the effect of temperature on insects in flight has observed a marked influence of severe environmental conditions, which prevented the insects being active (high wind velocities and low temperatures).

According to Nakamura and Kawasaki (1977), who worked on *Spodoptera lituna* (F.) sex pheromone and the size of the pheromone plume, indicated that the active area of the trap depends on the high wind velocities, increasing the probability that insects fly into the plume and hence be attracted to the trap. At low wind-speeds, the trap would have a small active area and subsequently attract and catch fewer insects.

Lewis and MaCaulay (1976) while working on the design and elevation of sex attractant traps for pea moth, *Cydia nigricana* (Steph.) has observed a strong influence of wind speeds on the pheromone trap performance.

Murlis and Bettany (1977), while working on the night flight towards a sex pheromone source by male *Spodoptera littoralis* (Boisd.) observed a strong vertical undulation pattern with horizontal zig-zagging as the source is approached by the moth.

Lingren et al., 1978; Lingren et al., 1980 have conducted research on the nocturnal activity of adult Lepidoptera, *Heliothis virescens* (F.) and *Helicoverpa zea* (Boddie), concluded that, they exhibit modes of activity that occur in definite sequence during the night.

The same kind of observations by them again in 1982 confirmed that there is a sequence of nocturnal activity in these noctuid moths which involves an initial period of oviposition interspersed with feeding during the early pair of the night, followed by an increase in the mating activity as the night progresses.

Dent and Pawar (1988), while working on the influence of moon light and weather on the catches of *Helicoverpa armigera* in light and pheromone traps concluded that, the environmental factors could be casually related to the trap performance and more or less coincided with the biological clock.

Pawar, et al (1988), who worked on development of sex pheromone trapping of *Helicoverpa armigera* at ICRISAT, INDIA, confirmed a standard lure containing 2 mg pheromone as effective one when used in a dry funnel traps.

Riley and co-workers (1992), conducted nocturnal observations on the emergence and flight behaviour of *H.armigera* in Central India, noted that moth emergence from the soil was observed to start at dusk and recruitment continued steadily throughout the first half of the night. They also concluded that there was a slight increase in activity in the second half of the night caused by males undertaking mate – finding flights.

2.2 Oviposition Behaviour:

Ever since **Ehrlich's and Raven's** (1964) paper on co-evolution of butterflies and plants, Lepidoptera has probably been the taxon in which the greatest number of species has been studied for some aspects of oviposition behaviour. They concluded that, in choosing a habitat or a plant individual on which to alight, females in some **Lepidopteran** species have been shown to use the physical parameters like, the amount of light, leaf shape, specific wave lengths (contribution to reflected light), plant volatiles combined at shown range with some component of plant reflectance is the visible spectrum.

Brantjes (1976) has shown that chemo tactile or olfactory stimulus may influence oviposition in *Hadena bicruris* (Noctuidae) at the post alighting stage of host choice.

Rausher (1983) noted that the cues used prior to alighting might act mostly to maximize oviposition rate and the overall chance of larval survival.

Traynier (1984) observed that *Pieris rapae* can learn to associate some colored papers and some combinations of sinigrin and visual stimuli to elicit oviposition at varying degrees in laboratory cage experiments.

Ramaswamy (1987), working on the behaviour of *Heliothis virescens* noted that, once the female lands on a plant, it may still reject it, physical and chemical factors reflecting its decision to oviposit or not.

In both the pipeline swallow tail (*Battus philenor*) and the Zebra swallow tail (*Eurytides marcellus*), the particular plants chosen by ovipositing females sustain a higher larval survival than the plants rejected by those females (Jones, 1987).

Rao (1991) observed that most of the eggs laid by *Helicoverpa armigera* on pigeon pea were on the flowers and tender pods and the infestation is typically seen only during the flowering phase.

2.3 Management strategies in control of *Helicoverpa armigera* in chickpea:

2.3.1 Botanical control: Efficacy of Neem products

Thakur (1988) worked on gram pod borer, *Helicoverpa armigera* in order to control it with a less toxic and ecofriendly insecticide, concluded that, neem seed kernel extract at 5% concentration was efficient in terms of profitability and cost effectiveness.

Sachan and Lal (1993) suggested that neem seed kernel extract was more effective for controlling *H. armigera* on chickpea, which gave a 40% reduction in infestation over other chemical insecticides.

Sinha (1993) concluded that there is no significant difference in the seed yields in the plots treated with neem emulsion (0.125%) and neem kernel extracts (5%).

According to Ujagir et al (1997), Azadiractin (Nimbicidine 0.03%) did not show any yield increase by reducing the pod damage caused by the pod borer, *H. armigera*, when compared to that of NPV or chemical insecticides in chickpea.

2.3.2 Biological control methods: Efficacy of *Helicoverpa* Nuclear Polyhedrosis Virus (NPV) against *H.armigera*

Jayaraj and Rabindra (1981) worked on efficacy of different treatments to control the grain pod borer quoted that an application of NPV (250 LE/ha) followed by Endosulfan (0.035%) was on par with 0.07% Endosulfan for the control of *H. armigera* on chickpea.

Bio efficacy of NPV in comparison with Endosulfan against pod borer on chickpea were tested in the fields in Maharashtra, India, in 1985-86 post-rainy season by Pawar (1987), observed a lower percentage of pod damage in Endosulfan (0.05%) treated plots followed by those treated with NPV (500 LE/ha).

Jayaraj et al.,(1987), working on NPV has recorded a significant control of the pest with an application of 250 LE/ha and the virus being effective in the evening hours than in the morning.

Sharma et al (1997) assessed different bio-pesticides for the management of *H.armigera* by NPV in chickpea and concluded that it gave the best control of the pest application of NPV resulted in increased grain yields in chickpea.

2.3.3 Mechanical control Methods: Role of Avifauna in reducing the borer damage in chickpea

According to W.E. Collinge, the well-known British authority, house sparrows bring food (caterpillars, soft bodied insects, etc.,) from 220 to 260 times per day.

A German ornithologist has estimated that a single pair of tits with their progeny destroy annually at least 120 million insect eggs or 150,000 caterpillars and pupae (Source – The book of Indian Birds by Salim Ali).

Ghode (1988), conducted research on the Avian predation of gram pod borer in Orissa, concluded that due to the presence of cattle egret (*Bubulcus ibis*) and River tern (*Sterna aurantia*), the pest population was reduced from 5-10 larvae/plant in mid January to a trace by the end of the month.

Wightman et al (1993) reported that predation by cattle egret might be increased by giving the birds easy access to the larvae by sowing on ridges or by optimizing row separation in a flat sowing.

Bhagawat (1997) provided bird perches to encourage predatory birds and stated that birds only visited plots that were not sprayed with chemical or botanical insecticides and their activity was intense in plots sprayed with NPV, where the birds fed on the dead virus – infected larvae.

2.3.4 Chemical control methods:

Dhurve (1985), working on the efficiency of different insecticides to control the noctuid, *Helicoverpa armigera* on chickpea in Maharashtra, India, noted that, Endosulfan at 0.5% has given significant yields compared to monocrotophos (0.04%), phosalone (0.05%), fenitrothion (0.05%), formothion (0.05%), quinalphos (0.05%) and cypermethrin (0.01%).

Rizvi (1986), stated that three sprays of 0.05% Endosulfan at 15 day intervals commencing at 50% flowering gave the most effective control of the pest, which proved to be more economical and profitable than other insecticides.

McCaffery, King, Walker, El-Nayir (1989), worked on development of resistance in *H.armigera* to synthetic pyrethroids from Andhra Pradesh, reported that *Helicoverpa* pest population were highly resistant to cyperermethrin and fenvelerate and moderately resistant to Endosulfan.

2.3.5 Integrated Pest Management strategies against *Helicoverpa armigera*

Reed et al (1980) reviewed the management strategies and approaches to manage *Helicoverpa armigera* (Hub.) on chickpea which covered population studies through pheromone and light traps, insecticide use, use of NPV, parasitoids, cultural practices and breeding for host-plant resistance.

Time of sowing has been shown to have considerable effect of *H.armigera* infection in a series of trials conducted by AICPIP in India, earlier sowings giving the least damage and best yields (Lal et al, 1980).

An experiment at ICRISAT, using a CDA spray of NPV gave more than 50% mortality of *H.armigera* larvae in a field of chickpea (Bhatnagar et al., 1982).

Saxena (1980) reported that experiments to investigate the provision of perches for birds have shown a substantial predation of larvae on the chickpea crop by insectivorous birds (ICRISAT, 1984).

Sarode et al (1995) concluded that application of NPV at 500 LE / ha plus the neem extract at 6 per cent gave the maximum reduction in larval numbers (79.8 and 65.2% at 7 and 14 days after spraying respectively) in chickpea crop.

According to Bhagwat (1997), an integrated pest management strategy using a botanical insecticide, a host specific virus to protect chickpea from pod borer showed the efficacy of this approach over local farmers in on-farm situation.

MATERIALS AND METHODS

Chapter III

Materials and Methods

Research on the **"Behavioural studies of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and its management in Chickpea"** were conducted at International Crops Research Institute for the Semi-arid Tropics, Patancheru, Andhra Pradesh, India during the post-rainy season 1999-2000. The materials, methods and methodology employed in conducting these studies are elucidated in this chapter.

3.1 Flight towards a sex pheromone source by *Helicoverpa armigera* (Hub.) (Lep: Noct), influence of weather parameters on the trap catches:

The present work is carried out at ICRISAT, patancheru location, A.P., India. (18^oN, 78^oE), from 13^{th} to 31^{st} January 2000, as part of the study on the behaviour and management of *H.armigera* (Hub.), which damage many crops, including legume crops, chickpea and pigeon pea.

To study the flight behaviour, the synthetic pheromone, a mixture of (Z) -11- hexadecinal and (Z) –9- hexadecinal in the ratio of 97:3, was used, which was obtained from the Natural Resources Institute, Chatam, Kent, U.K. 2 mg pheromone was dispended from a cylindrical polythene vail, 2 cms long and 1 cm cross section diameter. This was suspended to the roof of the trap (as shown in the figure), at a height of 1.5m above the ground nearer to the crop canopy.

Catches of *H.armigera* males in three ICRISAT standard dry/no exit funnel pheromone traps (Pawar et al., 1984) were recorded at bi-hourly intervals from 20.00 to 06.00 h for each night. The three pheromone traps were placed at least 500m apart in three different cropping locations, BL_3, BW_3 and RP_8 of ICRISAT farm. The traps stood at a height of 1.5m from the ground. The wind direction was predominantly North-Westerly during the experimental period.

The hourly meteorological data, like temperature (°C), relative humidity (%), and wind velocity (kmph) were recorded at the trap point. Hourly means were calculated for each environmental class. Simple correlation analysis were done to know the effect of weather parameters on the moth catch.

For studying the flight pattern of the males towards a pheromone source, night vision goggles (NVG) were used, since, even in bright moon light *H.armigera* males cannot be seen beyond about 2m. Since the depth of the field is inadequate for small moving targets and also due to the grained and strong scintillates of the image at low light levels, supplementary infrared illumination, which greatly improves image brightness and definition in the NVG, thereby increasing depth of the field were used in order to overcome these limitations.

Two battery run lights (BRK Handey Beam™, IL) – 60 Hz, 0.05Amp were placed 6m apart on the wind line through the attractant source and shining towards the source. The beams were filtered by covering the light source with a red polythene filter paper, which normally pass light in the wave length of about 1500 nm only, which is well beyond the sensitivity found in the eyes of most insects except at very high intensity. (Burkhardt, 1964)

Flight behaviour was observed from a position of about 8m to the side of the expected flight path and from upwind of the source looking along the path.

3.2 Oviposition behaviour of *Helicoverpa armigera* to flower color variation in pigeonpea (*Cajanus cajan*):

3.2.1 Host plants:

Pigeon pea cultivars with yellow flower color (Bahar and ICPL 99092) and with red flower coloration (ICP 7035 and ICPL 86012) which were susceptible to *Helicoverpa* attack were chosen for the experiment. These genotypes were grown on pesticide free area, under Genetic Resources Enhancement Program (GREP), ICRISAT. The flowering twigs were collected during peak flowering stages of the genotypes mentioned.

3.2.2 Study Organisms:

The 5th and 6th instar larvae were collected from the chickpea fields, ICRISAT farm, and were allowed to pupate under laboratory conditions. When ever the male moths are in shortage, the female moths that were released from the pupae were paired with the male moths that were trapped in the pheromone traps .

3.2.3 Oviposition preference Tests:

The oviposition preference of *H.armigera* moths towards the flower color of pigeonpea was checked in both "Choice" and "No choice" situations.

Fresh flowering twigs brought from the field were placed in a conical flask (150ml), filled with water, plugged with cotton wool, exposing the flowers. The cut ends are kept immersed in water in order to prevent desiccation. Due care has been taken to retain exactly 100 flowering buds, of equal size, per conical flask. Two such flasks one each with red and yellow flowering bunches were placed in a wooden cage of dimensions – 33.5 X 25.5 X 31.2 cm.

The sidewalls of the cage were covered with glass, except on one side, which was covered with cloth to allow minimum aeration required for the moths to be active and to facilitate release of moths and changing diet.

A dram cup of honey water dipped cotton wool was placed in the center of each cage as a feed for adults, and replaced every other day. The flowering twigs were replaced after every 3 days, as they were prone for desiccation.

Five pairs of moths were released once the setup was complete. Each morning the eggs were counted and removed gently with the help of a camel hair brush in order to over come the "Density Depended Avoidance" for further oviposition by the female moths. The egg counts were taken until the oviposition lasted.

Two tailed student-'t' test was performed, on the mean number of eggs laid on the two different flower colors, to test the null hypothesis under choice and no choice conditions.

3.3 Integrated Management of *Helicoverpa armigera* on chickpea (*Cicer arietinum*):

Experiments on "Integrated Management of *Helicoverpa armigera* on Chickpea" were conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru location, India during post-rainy season 1999-2000.

3.3.1 Experimental Design:

The research was conducted at Black Precision (BP)14 field of ICRISAT farm. An area of 9000 m^2 was divided into 28 plots, each measuring 288 m^2 (24 X 12 m), to conduct the experiment with seven treatments in four replications each. Randomized block design (RBD) was used to conduct the trail. (Fig 8)

3.3.2 Sowing:

A high yielding, desi , medium duration variety, ICCC 37 (Kranti), was used in this trial. Seed treatment with Mancozeb @ 2g kg^{-1} of seed was done to reduce the incidence of seed borne fungal diseases, such as, collor rot and root rot . The treated seeds were sown on 22nd October 1999, with a spacing of 60 cm between the rows and 20 cm within a row.

3.3.3 Treatments:

The efficacy of the following treatments on the gram pod borer, *Helicoverpa armigera*, was studied:

T_1	:	Neem spray (1500 PPM)
T_2	:	NPV application (250 LE ha^{-1})
T_3	:	Fixing bird perches (1 perch $plot^{-1}$)
T_4	:	Endosulfan 35 EC spray(0.07%)
T_5	:	IPM practice (T_1+T_2+T_3+T_4)
T_6	:	Annona Leaf extract spray (0.05%)
T_7	:	control

(a) Neem:

Neem 1500 PPM, (Neem seed Kernel – Triterpenoids) containing Azadiractin was obtained by ICRISAT and was used in the experimental plot. 1500-PPM concentration was mixed in a litre of water. So, to spray in an area of 288 m^2 plot, 50 ml of stock solution was mixed with 10 l of water and sprayed.

(b) NPV:

Nuclear polyhedrosis virus produced at ICRISAT- NPV laboratory was used for the studies. The NPV stock solution was prepared in such a way that 1 ml of NPV solution equals to one larval equivalent containing $6x10^9$ polyhedral inclusion bodies (PIB's). Since, virions were susceptible to Ultra-violet rays of sunlight, the spraying was done in the evening hours. In order to protect the polyhedron particles from UV rays, Robin Blue was mixed in the spray solution @ 1 ml l^{-1} of spray fluid. NPV was used @ 250 LE ha^{-1}

(c) Bird Perches:

Dried up tree branches were cut in the shape of 'T' to create a natural tree like appearance in the field, to be used as a perch by the visiting bird. The vertical height of the perch was about 1.5 m from ground, a suitable height for insectivorous birds like drongo, to rest and search for the larvae in the crop canopy. 20 days after sowing (DAS) the perches were installed @ one perch $plot^{-1}$ till crop harvest.

(d) Endosulfan:

Endosulfan 35 EC which was obtained by ICRISAT was used in the experimental plot. To prepare 0.07% concentration, 2 ml of the stock solution was mixed in a litre of water.

(e) Annona Leaf Extract:

For the first time, efficacy of Annona leaf extract was tested against the pod borer. Since, there was no marketed product available containing Annona, Annona leaves were collected from the agro-forestry area of ICRISAT farm, oven dried and powdered. Stock solution was prepared by mixing the Annona leaf powder @ 5 g L^{-1} of water, soaked over night and filtered before spraying. Thus prepared stock solution with 0.05%

concentration was sprayed @ 10 l $plot^{-1}$. To increase the stickiness of the spray fluid, detergent powder @ 1 g l^{-1} was mixed and sprayed.

The above-mentioned treatments were given four times at 15 days interval during the cropping period. The sprays were initiated after the pest population was above ETL. (2 small larvae $plant^{-1}$). The sprays were imposed on 48, 67, 82 and 97 DAS.

3.3.4 Method of Recording Observations:

(a) Pest Population:

Number of small sized larvae (first and second instar), medium sized larvae (third and fourth instar) and large sized larvae (fifth and sixth instars) were recorded on twenty randomly selected plants, $plot^{-1}$. The observations were taken at weekly intervals starting from 45 DAS till the crop maturity.

(b) Pod Damage:

In order to avoid the border effects, 3 rows on each side, and 5 m on other two sides was left and observations were taken from the central 15 rows of 14 m each. So, the net plot area was 8.4 X 14 m i.e., 117.6 m^2.

Twenty individual plants were selected randomly from each of the net plot and all the pods were collected .The pods were sorted as, the pods damaged by the pod borer and healthy ones. Percentage pod damage was worked as below:

$$\text{Percentage pod damage} = \frac{\text{No.of damaged pods}}{\text{Total no. of pods}} \times 100$$

(c) Yield:

The plants in the net plot area were harvested individually in each plot at 126 DAS. Threshed grains were cleaned, weighed and net plot yields were obtained. The pods collected from 20 plants which were removed for assessing pod damage were also threshed, cleaned, weighed and added to the net plot yield.

3.3.5 Cost-benefit ratio:

To assess the economics of different treatments in the management of *H.armigera*, cost benefit ratio was worked out taking into account the total cost of insecticidal application ha^{-1} and the total income ha^{-1}.

3.3.6 Statistical Analysis:

The statistical analysis of the data on the performance of different treatments on the gram pod borer were analyzed by using the standard analysis of variance procedures in randomized block design. The data on percentages were transformed into arc sin values and the population into square root values before analysis. The test of significance was assessed using the least significant difference obtained by following the RBD at 5% level (Snedecor and Cochran, 1982). All statistical analysis were performed using statistical package '**GENSTAT**', developed by Rothemsted Experimental Station, Hertford shire, England.

3.3.7 Weather data:

The weather parameters viz., maximum, minimum temperatures (°C), total rainfall (mm) and relative humidity (%) were recorded daily at 0710 h in Agro-Meteorological observatory at ICRISAT. These parameters were obtained from Agro climatology division of ICRISAT. The mean weather data that prevailed in every standard week during cropping season were calculated.

3.3.8 Monitoring *H.armigera* population using sex pheromone trap:

The three traps that were used to monitor the flight pattern were used to monitor the pest population through out the cropping season. The number of male moths caught per trap were counted and removed daily. Total number of moths caught per standard week were worked out, to monitor the fluctuations in the population. The pheromone vials were renewed once in 30 days.

RESULTS

Chapter IV

Results

The results of the studies on the behavioural aspects of *Helicoverpa armigera*, the gram pod borer, that included peak moth activity, flight pattern towards the pheromone source, ovipositional preference towards the flower color variation in pigeonpea and development of Integrated Pest Management (IPM) in chickpea, during post-rainy season 1999-2000, at International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, were presented in this chapter.

4.1.1 *Helicoverpa armigera* male moth activity, influence of weather on the pheromone trap catches, peak moth activity and flight pattern towards the pheromone source:

The pheromone trap catches showed no distinct peak, but fluctuated every day, with the higher catch occurring on different days in the three traps (Fig.1). It could simply reflect differences in the number of *Helicoverpa armigera* present in the nearby crops. A total of 450 males were caught in the three different pheromone traps observed during the study period.

The mean night temperature during the study period ranged from 15.4 to 19.9 ^{0}C, while the mean hourly temperature ranged from 22.0 to 13.8 ^{0}C. The mean humidity during the study period ranged from 73.8 to 53.7 %, while the mean hourly humidity was more variable, ranging from 37.6 to 88.4%. The mean night wind velocities were more variable between nights and ranged from 2.6 to 8.4 kmph during the study period. Mean hourly wind velocity was not much varying, which ranged from 3.4 to 5.7 kmph.

The mean hourly temperature and mean hourly wind velocity decreased during the night, while the relative humidity increased to a plateau at about 04.00 h and remained high until dawn (Fig.3).

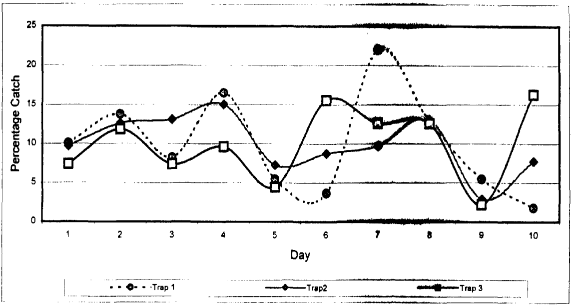


Fig.1 The nightly catch of Helicoverpa armigera males in the three pheromone traps during the study period

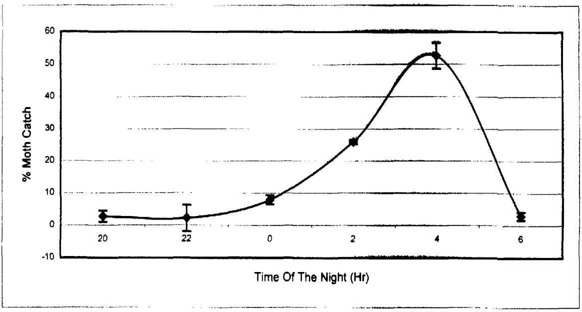


Fig.2 The hourly mean number of Helicoverpa males caught in the pheromone traps (the vertical bars indicate the Standard Error of the mean catch).

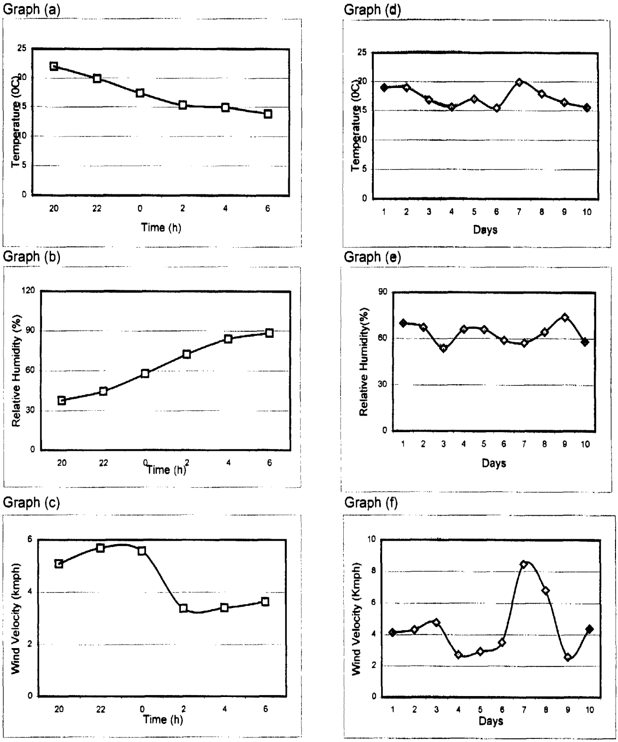


Fig.3 The mean hourly (a) Temperature ; (b) Relative Humidity and (c) Wind Velocity and the mean nightly (d) Temperature ; (e) Relative Humidity and (f) Wind Velocity during the study period.

4.1.2 Mean Hourly catches:

The mean number of moths caught per hour in the pheromone traps increased steadily during the night with a skewed distribution and a peak catch of the moths (52.7%) was observed between 02.00 h and 04.00 h, followed by a gradual decrease to dawn (Fig.2).

4.1.3 Insect Activity:

The hourly mean estimates of each environmental factor were divided into a number of classes. The percentage of occasions on which trap catches were recorded in each class, for each environmental factor, was divided and used as a measure of the effect of environment on insect activity (Table 1). The only occasions on which no moths were recorded in the pheromone traps corresponded to the four periods when the temperature was 23 degrees centigrade and above. On two occasions, when the temperature was below 11^{0}C, only 3% of total moth catch was recorded. The trap catches (and hence in this context, insect activity) appeared to be little effected by variations in temperatures above 11^{0}C degrees centigrade. The wind velocity and humidity levels were not sufficiently extreme to prevent catches occurring. However, there was slight reduction in the percentage catches when both, relative humidity and wind velocities were high.

4.1.4 Trap performance and weather:

The relationships between trap performance and weather are presented as histograms of mean percentage catch of the catch in each environmental class, as a percentage of the total catch divided by the frequency of the environmental class (Fig.4).

The effect of wind velocity on mean percentage pheromone trap catches appeared to be more variable, but catches were consistently higher when wind velocities ranged between 5 and 10 kmph.

High mean percentage pheromone trap catches occurred when temperatures were between 12 and 18^{0}C, but response to relative humidity was highly variable. On the whole, the correlation matrix (Table 2) clearly shows that the temperature and wind

Table 1. The percentage of occasions when catches of *Helicoverpa armigera* . were recorded in the pheromone traps at different levels of temperature, relative humidity and wind velocity

Temp (^{0}C)	% of catch occasions	n	RH (%)	% of catch occasions	n	Wind velocity (Kmph)	% of catch occasions	n
25.9-25	0	1	25-29.9	2.32	3	12-12.99	1	1
24.9-24	0	1	30-34.9	1	2	11-11.99	0	0
23.9-23	0	2	35-39.9	1.99	3	10-10.99	10	1
22.9-22	0.5	4	40-44.9	1.27	7	9-9.99	37	1
21.9-21	2.25	4	45-49.9	1.65	4	8-8.99	2	4
20.9-20	2.99	3	50-54.9	4.4	3	7-7.99	1.8	5
19.9-19	4.49	8	55-59.9	3.5	5	6-6.99	13.99	3
18.9-18	11.75	4	60-64.9	11.5	2	5-5.99	6.8	5
17.9-17	7.25	4	65-69.9	17	4	4-4.99	3.49	8
16.9-16	7.48	6	70-74.9	4	5	3-3.99	4.49	8
15.9-15	14.99	6	75-79.9	11.25	4	2-2.99	10.99	11
14.9-14	11.27	7	80-84.9	12.99	6	1-1.99	9.91	12
13.9-13	13.75	4	85-89.9	10.8	5			
12.9-12	11.25	4	90-94.9	18.75	4			
11.9-11	2	1	95-99.9	0.99				
10.9-10	1	1						

n = The total number of occasions recorded in each class

Temperature (^{0}C), Relative Humidity (%) and wind velocity (kmph) were hourly means

(a)

(b)

(c)

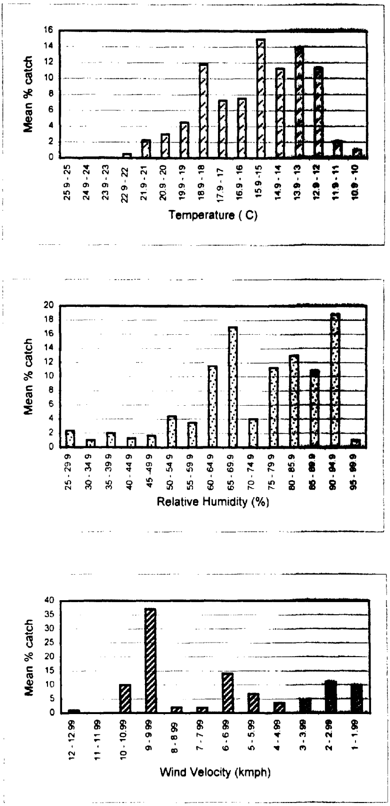


Fig.4 The mean percentage catch of Helicoverpa armigera males (catch in each environmental class as a percentage of the total catch divided by the frequency of the environmental class) caught in the pheromone traps aganist (a) Temperature ; (b) Relative Humidity and (c) Wind Velocity.

velocities are negatively correlated with moth catch, whereas relative humidity is positively correlated.

4.1.5 Fight pattern and orientation towards a sex pheromone source:

Flight behaviour of male *Helicoverpa armigera* towards the pheromone source was observed from a position of about 8 m to the side of expected flight path and from up wind of the source looking along the path. Male moths showed a consistent flight pattern, and in favorable conditions (wind velocities > 5 kmph), distinct successive stages of flight were found, performed by almost 80% of about 200 moths identified as *Helicoverpa armigera* on the strict criterion of their halting their forward progress on the pheromone septum or in the air close to it (some insects of about the size of *Helicoverpa armigera* flew straight-wind past the capsule without any apparent recognition of it).

In steady wind (during early hours, around 03.00h), the moths were first seen in straight and level flight, making rapid progress directly upwind at an altitude of between 0.5m and 2.0m, this portion of the flight was in view of the NVG. At a distance from the source usually within the range of 2 to 4 m, and apparently for a given fixed wind velocity (3.38 kmph), the moths abruptly reduced both ground speed and "speed of flight", performing subsequently slower, more undulating flight. Although the flight paths contain some deviations in the horizontal plane, well-defined zig-zagging took place only as undulation in the vertical plane (Fig.5)

Closer to the source, forward progress were halted and vertical oscillations increased until the moth was hovering downwind from the source and moving up and down over a distance of upto 1 m while maintaining its upwind heading. Hovering time ranged from 10 to 35 s during which occasional, less regular, short, downwind, flights and generally exploratory movements were made. About half of these moths then turned and few downwind, often climbing to an altitude of order 2 to 3m where they were usually lost from view. About half of them again landed near or on the septum before flying away in a gentle downward climb.

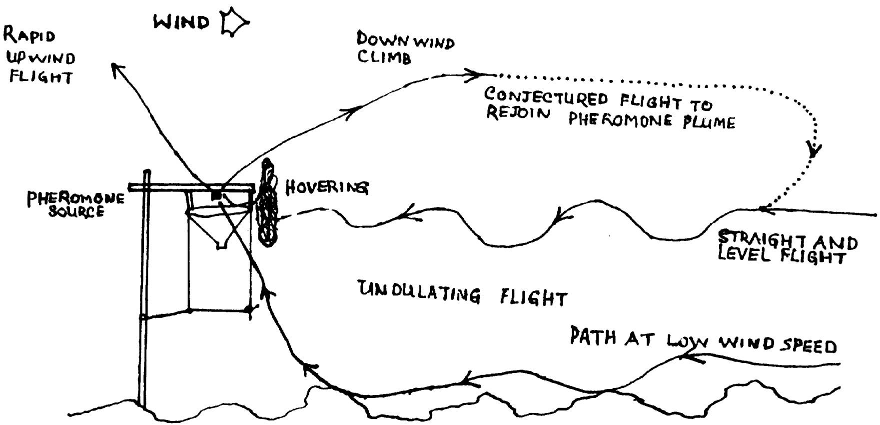
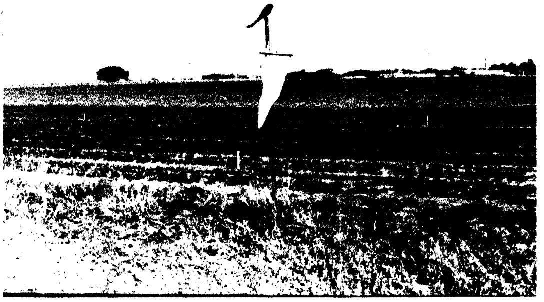
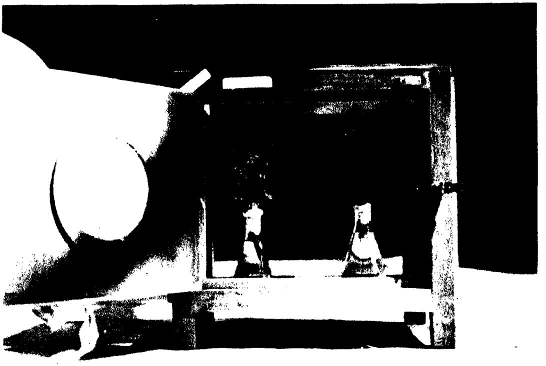


Fig. 5. **Generalized flight and orientation pattern of Helicoverpa armigera to the pheromone source**



Pheromone trap placed in the field meant for monitoring male moth activity



Experimental set up for oviposition preference tests

The moths which did land usually settled for upto about 1 minute before leaving the septum either downwind or in a rapid climbing upwind flight, again generally out of illuminated region.

During the peak moth activity (at around 03.00h), though the wind velocity was moderate (3.4 + 1.1 kmph), large number of moths have been trapped. This may be because of the huge activity during which moths are seen coming in large number (>4 at a time), and the competition to hover around the septum. The activity is so high, that moths are seen being trapped due to the collision between themselves. The moths that are not trapped were seen touching the septum before flying away in a gentle downwind climb.

One couple of nights, moths were observed from a greater distance, 10 to 12 m it was then possible to see them climbing from the septum and at an altitude of some few meters swiftly turning to head and fly downwind and then dropping to the original approach height about 5 to 6 m from the source. It was very difficult to see the moths after this because the image they produced in the NVG at such distance could be confused with that of the other insects of similar size.

4.2 Oviposition preference of *Helicoverpa armigera* to flower color variation in pigeonpea:

The results of the oviposition preference tests that were conducted to assess the behaviour of *Helicoverpa armigera* to oviposit on different genotypes of pigeonpea according to flower color variation were presented in Table.3 and Fig.6

The results of the six paired comparisons under 'choice test', where the ovipositing female moth had a choice between the yellow and red color flowers, the mean number of eggs laid/100 buds/day were significantly higher in the yellow color flowers 83.3 against red color flowers 36.

Under 'no-choice' conditions also, the mean oviposition was significantly higher in yellow colored flowers, 64 compared to red color flowers, 54.7.

Table 2. Correlation matrix showing the relation between the percentage moth catch and the weather parameters

	Temp (^{0}C)	RH (%)	Wind velocity (kmph)
Percentage moth catch	-0.499	0.549	-0.654

Table 3. Oviposition preference of *Helicoverpa armigera* to flower color variation in pigeonpea.

CHOICE TEST:

Flower color	Mean no. of eggs laid/100 buds/day	Variance
Yellow	83.3	5619
Red	36	1064

Daily means represent results of 6 paired comparisions
Test statistic, t= 3.32
Means are significantly different (P=0.05), by the paired ' t ' test

NO-CHOICE TEST:

Flower color	Mean no. of eggs laid/100 buds/day	Variance
Yellow	63.97	3841
Red	54.69	4474

Daily means represent results of 6 paired comparisions
Test statistic, t= 0.59
Means are significantly different (P=0.05), by the paired ' t ' test

Fig. 6 Oviposition Preference Of *Helicoverpa armigera* To Flower Color Variation In Pigeonpea

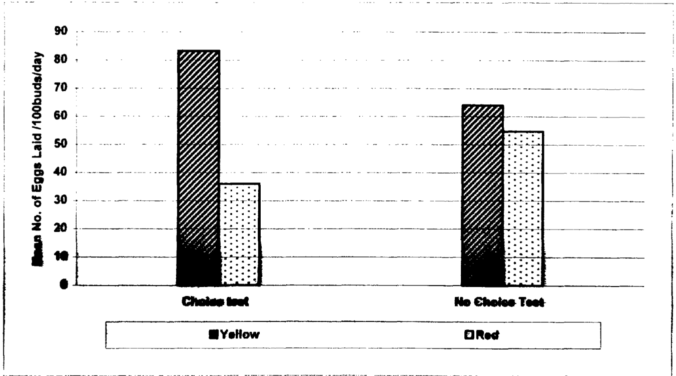


Fig.7 Weather Data During The Cropping Season 1999 - 2000 At ICRISAT , Patancheru Locatio

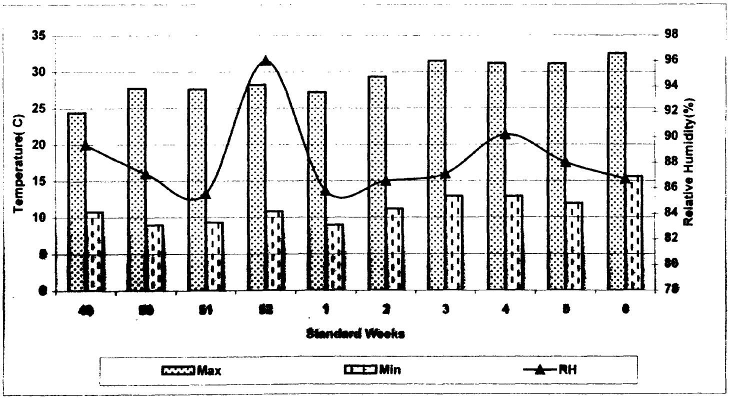


Fig 8. Layout of the Experimental plot

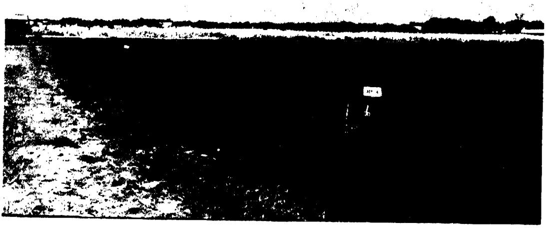
Crop : Chickpea
Gross Area : $9000 m^2$
Plot size : 24 X 12 m
Gross plot area: $288\ m^2$
Net plot area : $117.6 m^2$

Variety: ICCC 37 (Kranti)
Replications: 4
Treatments: 7
Design: RBD

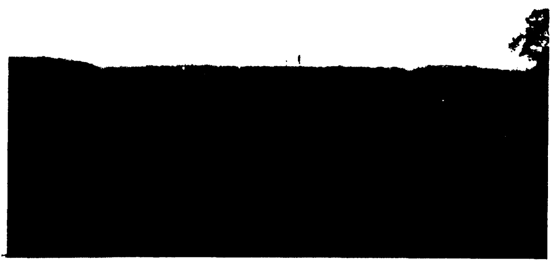
N

RI	T1	T2	T6	T5	T3	T4	T7	24m
RII	T5	T1	T2	T4	T7	T3	T6	24m
RIII	T6	T2	T3	T1	T4	T5	T7	24m
RIV	T4	T1	T3	T5	T7	T2	T6	24m
	12m	12m	12m	12m	12m	12m	12m	

T1 = Neem 1500PPM
T2 = NPV @ 250 LE ha^{-1}
T3 = Erecting bird perches
T4 = Endosulphon 0.07 per cent
T5 = Integrated Pest Management practices
T6 = Annona Leaf extract 0.05 per cent
T7 = Control



A field view of the experimental plot



An ecofriendly plot with bird perches meant for Helicoverpa management

4.3 Development of Integrated Pest Management Practices in Chickpea

4.3.1 Efficacy of different plant protection options against small sized larvae of *Heicoverpa armigera*:

The efficacy of different treatments on the suppression of small size larvae (first and second instar) of *Helicoverpa armigera* were studied and the results were presented in Table4 and Fig.9.

As the results reveal, there was no significant difference in the larval population in the pre-treatment counts that were taken on 45 DAS, before imposing the treatments.

The first and second instar larvae were quite effectively controlled by all the treatments that were tested against *H.armigera*. Endosulfan emerged as a superior spray, which resulted in a 30 per cent overall reduction in the pest population, when compared to the unsprayed plots. NPV and annona sprays were on par with each other, which resulted in reducing the pest by 24 and 23 percentages respectively, over control. In the IPM plots, small sized larvae were kept suppressed by 21 percent effectiveness than the control plots. Bird perches haven't shown a concomitant decrease in the pest population but resulted in overall reduction in the pest by 15 percent.

4.3.2 Efficacy of different treatments against medium sized larvae of *Heicoverpa armigera:*

In order to access the efficacy of different treatments against the 3rd and the 4th instar (Medium sized) larvae of gram pod borer *Helicoverpa armigera*, studies were conducted and the results are presented in Table.5 and Fig.10. The larval counts that were taken the day before initiating the treatments (45DAS) were not significantly different in all the plots.

All the treatments that were tested were significantly superior in reducing the medium sized larval population efficiently than the unsprayed control plots.

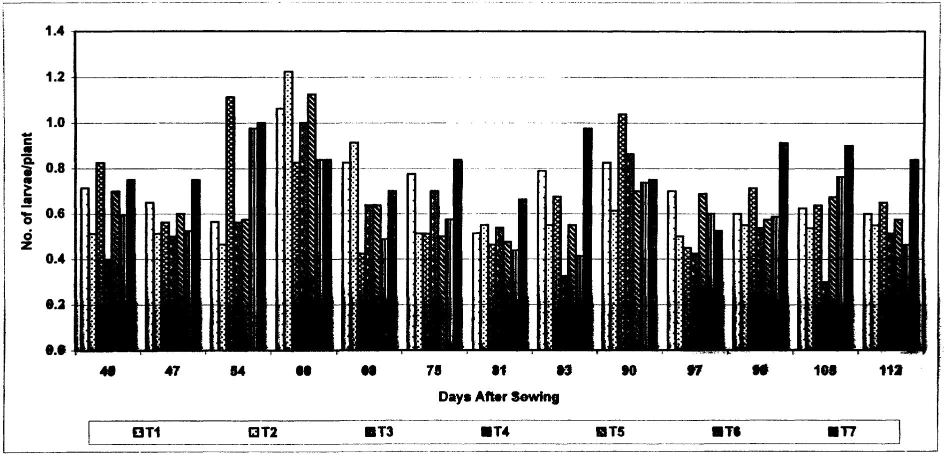
Table 4 . Efficacy of different treatments against small sized (1st and 2nd instar) larvae of *Helicoverpa armigera*.

Sl. No.	Treatment	DAS / DAT	Number of small sized larvae per plant												
		DAS	45	47	54	66	68	75	81	83	90	97	98	105	112
		DAT	Pre T	1	6	18	1	7	13	1	7	14	1	7	14
1	T1 - Neem - 1500 EC		0.713	0.650	0.565	1.063	0.825	0.775	0.513	0.788	0.825	0.700	0.600	0.625	0.600
			(0.870)	(0.831)	(1.147)	(1.051)	(0.918)	(0.901)	(0.730)	(0.907)	(0.903)	(0.852)	(0.790)	(0.816)	(0.795)
2	T2 - NPV 250 LE ha^{-1}		0.513	0.513	0.465	1.225	0.913	0.513	0.550	0.550	0.613	0.500	0.550	0.538	0.550
			(0.749)	(0.729)	(0.966)	(1.109)	(0.973)	(0.749)	(0.766)	(0.772)	(0.811)	(0.738)	(0.774)	(0.761)	(0.760)
3	T3 - Bird perches		0.825	0.563	1.113	0.825	0.425	0.513	0.463	0.675	1.038	0.450	0.713	0.638	0.650
			(0.930)	(0.776)	(1.069)	(0.923)	(0.672)	(0.737)	(0.710)	(0.836)	(1.028)	(0.680)	(0.872)	(0.818)	(0.835)
4	T4 - Endosulfan 0.07%		0.400	0.500	0.563	1.000	0.638	0.700	0.538	0.325	0.863	0.425	0.538	0.300	0.513
			(0.638)	(0.739)	(0.779)	(1.012)	(0.825)	(0.860)	(0.761)	(0.607)	(0.935)	(0.677)	(0.764)	(0.588)	(0.742)
5	T5-IPM		0.700	0.600	0.575	1.125	0.638	0.500	0.475	0.550	0.700	0.688	0.575	0.675	0.575
			(0.861)	(0.795)	(0.962)	(1.073)	(0.812)	(0.733)	(0.724)	(0.775)	(0.854)	(0.857)	(0.784)	(0.840)	(0.788)
6	T6 - Annona leaf extract 0.05%		0.594	0.525	0.975	0.838	0.488	0.575	0.438	0.413	0.738	0.600	0.588	0.763	0.463
			(0.823)	(0.754)	(1.110)	(0.937)	(0.725)	(0.776)	(0.693)	(0.669)	(0.881)	(0.803)	(0.792)	(0.889)	(0.707)
7	T7 - Control		0.750	0.750	1.000	0.838	0.700	0.838	0.663	0.975	0.750	0.525	0.913	0.900	0.838
			(0.889)	(0.885)	(1.015)	(0.940)	(0.860)	(0.855)	(0.840)	(1.009)	(0.878)	(0.752)	(0.970)	(0.970)	(0.916)
	Standard error difference		0.088	0.074	0.108	0.088	0.108	0.093	0.084	0.083	0.115	0.08	0.075	0.092	0.115
	Least significant difference		0.188	0.155	0.227	0.185	0.227	0.197	0.176	0.174	0.243	0.169	0.158	0.193	0.241

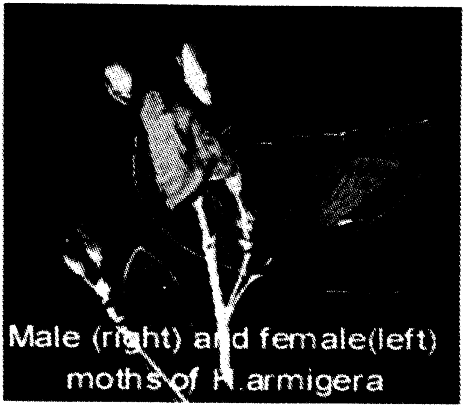
Figures in parentheses are square root transformed

Significant at 5% level (P=0.05)

FIG. 9 EFFICACY OF DIFFERENT TREATMENTS AGAINST SMALL SIZED (I & II INSTAR) LARVAE OF *HELICOVERPA ARMIGERA* ON CHICKPEA



T1-Neem 1500 EC
T2-NPV 250LE /Ha
T3-Bird Perches
T4-Endosulphon 0.07%
T5-IPM
T6-Annona Leaf Extract 0.05%
T7-Control



External morphology of the Gram Pod Borer, *Helicoverpa armigera*

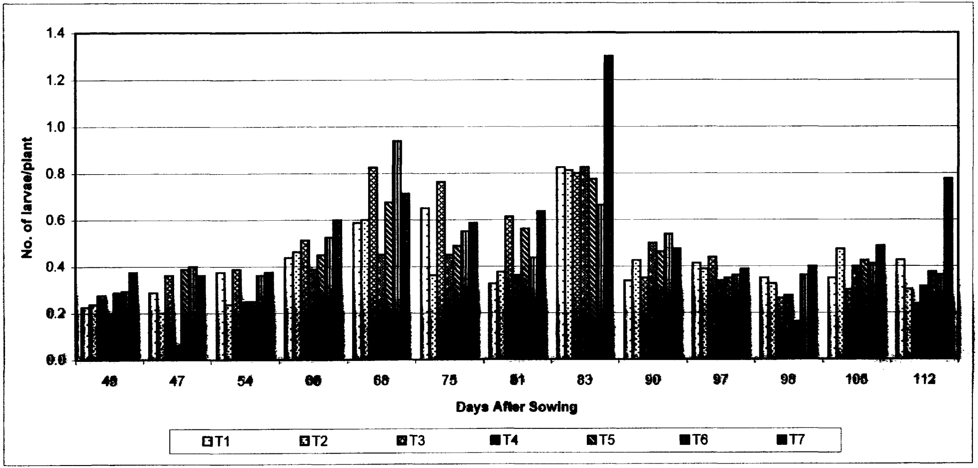
Table 5. Efficacy of different treatments against medium sized (3rd and 4th instar) larvae of *Helicoverpa armigera*.

Sl. No.	Treatment	DAS / DAT	Number of medium sized larvae per plant												
		DAS	45	47	54	66	68	75	81	83	90	97	98	105	112
		DAT	Pre T	1	6	18	1	7	13	1	7	14	1	7	14
1	T1 - Neem - 1500 EC		0.2250	0.2875	0.3750	0.4375	0.5875	0.6500	0.3250	0.8250	0.3375	0.4125	0.3500	0.3500	0.4250
			(0.517)	(0.578)	(0.640)	(0.690)	(0.793)	(0.833)	(0.599)	(0.925)	(0.620)	(0.672)	(0.618)	(0.632)	(0.676)
2	T2 - NPV 250 LE ha^{-1}		0.2375	0.2000	0.2375	0.4625	0.6000	0.3625	0.3750	0.8125	0.4250	0.3875	0.3250	0.4750	0.3000
			(0.517)	(0.497)	(0.529)	(0.708)	(0.799)	(0.635)	(0.644)	(0.925)	(0.685)	(0.654)	(0.610)	(0.715)	(0.578)
3	T3 - Bird perches		0.2750	0.3625	0.3875	0.5125	0.8250	0.7625	0.6125	0.8000	0.3500	0.4375	0.2625	0.3000	0.2375
			(0.568)	(0.635)	(0.661)	(0.719)	(0.919)	(0.899)	(0.802)	(0.915)	(0.631)	(0.697)	(0.542)	(0.591)	(0.535)
4	T4 - Endosulfan 0.07%		0.2000	0.0625	0.2500	0.3875	0.4500	0.4500	0.3625	0.8250	0.5000	0.3375	0.2750	0.4000	0.3125
			(0.484)	(0.326)	(0.541)	(0.648)	(0.703)	(0.705)	(0.617)	(0.935)	(0.736)	(0.606)	(0.561)	(0.664)	(0.596)
5	T5-IPM		0.2875	0.3875	0.2500	0.4500	0.6750	0.4875	0.5625	0.7750	0.4625	0.3500	0.1625	0.4250	0.3750
			(0.575)	(0.652)	(0.534)	(0.691)	(0.847)	(0.725)	(0.779)	(0.898)	(0.711)	(0.629)	(0.453)	(0.679)	(0.630)
6	T6 - Annona leaf extract 0.05%		0.2934	0.4000	0.3625	0.5250	0.9375	0.5500	0.4375	0.6625	0.5375	0.3625	0.3625	0.4125	0.3625
			(0.550)	(0.634)	(0.634)	(0.745)	(0.981)	(0.769)	(0.690)	(0.842)	(0.755)	(0.641)	(0.636)	(0.673)	(0.637)
7	T7 - Control		0.3750	0.3625	0.3750	0.6000	0.7125	0.5875	0.6375	1.3000	0.4750	0.3875	0.4000	[illegible]	0.7750
			(0.640)	(0.629)	(0.648)	(0.796)	(0.862)	(0.796)	(0.828)	(1.162)	(0.716)	(0.849)	[illegible]	[illegible]	[illegible]
	Standard error difference		0.0910	0.1030	0.0720	0.1090	0.1070	0.0660	0.0920	0.0760	0.0610	0.0820	[illegible]	0.0730	0.0960
	Least significant difference		0.1930	0.2170	0.1510	0.2300	0.2250	0.1400	0.1950	0.1600	0.1290	0.1720	0.1810	0.1550	0.2030

Figures in parentheses are square root transformed

Significant at 5% level (P=0.05)

FIG. 10 EFFICACY OF DIFFERENT TREATMENTS AGANIST MEDIUM SIZED (III & IV INSTAR) LARVAE OF HELICOVERPA ARMIGERA ON CHICKPEA



T1-Neem 1500 EC
T2-NPV 250LE /Ha
T3-Bird Perches
T4-Endosulphon 0.07%
T5-IPM
T6-Annona Leaf Extract 0.05%
T7-Control

Neem spray was quite effective in controlling the 3rd and 4th instar larval population of *Helicoverpa armigera*. This can be viewed from the overall reduction in the pest by 22 percent, over control. NPV treatment was effective in reducing the pest by 27 percent, which ranked only next to endosufan, which suppressed the pest by 32 per cent. Bird perches, though not much effective than other treatments, have shown a decline in the overall reduction in the pest by 14 per cent, when compared to control. Annona leaf extract spray was the least effective treatment among others that were tested, but was observed to reduce the pest by 13 per cent, which was on par with the bird perches.

4.3.3 Efficacy of different treatments against large sized larvae of *Heicoverpa armigera:*

Studies were conducted to access the efficacy of different treatments in the management of large sized larvae (5th and 6th) instar of *Helicoverpa armigera*, and the results were presented in table6 and Fig11 .Pre treatment population counts were on par in all the plots that were taken on 45 DAS.

Four sprays of Neem that were given at 15 days interval have given considerable reduction in the large sized larval population. The overall effectiveness of neem spray was about 32 per cent higher than the control, but was on par with the Annona spray (33 per cent) and less effective than NPV, endosufan and IPM. NPV treatment has resulted in a significant reduction in the large sized larvae population with 42 percent of effectiveness than control. Bird perches were very much effective in attracting the insectivorous birds, thereby increasing the predation of large sized larvae quite effectively. This resulted in a significant decrease in the larval population by 48 percent, which was on par with the IPM plots, which also had bird perches. Endosulfan was the most effective spray, which resulted in 65 percent decrease in the larval population, compared to control. On the whole, all the treatments were significantly effective in reducing the large sized larval population than the unsprayed plots (control).

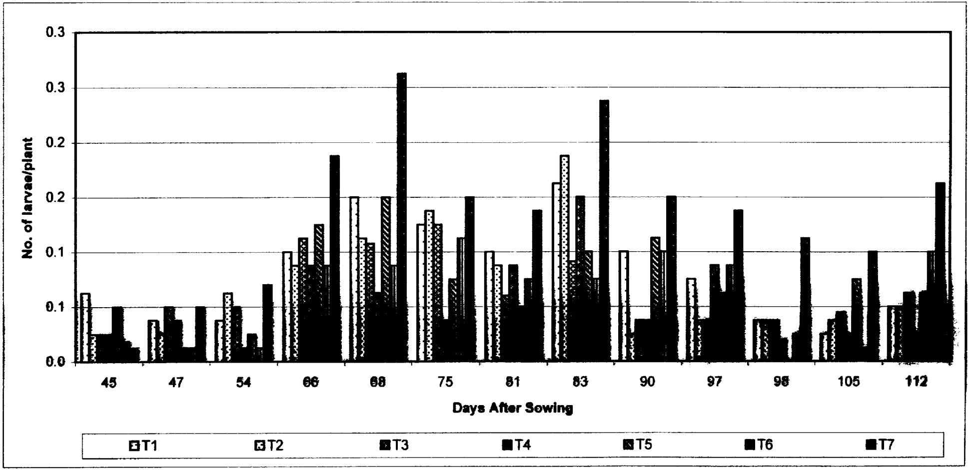
Table 6 . Efficacy of different treatments against large sized (5th and 6th instar) larvae of *Helicoverpa armigera.*

		Number of large sized larvae per plant												
Sl.		DAS	45	47	54	66	68	75	81	83	90	97	98	105	112
No.	Treatment	DAT	Pre T	1	6	18	1	7	13	1	7	14	1	7	14
1	T1 - Neem - 1500 EC		0.0625	0.0375	0.0375	0.1000	0.1500	0.1250	0.1000	0.1625	0.1000	0.0750	0.0375	0.0250	0.0500
			(0.326)	(0.288)	(0.288)	(0.380)	(0.432)	(0.395)	(0.385)	(0.453)	(0.369)	(0.339)	(0.293)	(0.270)	(0.293)
2	T2 - NPV 250 LE ha^{-1}		0.0250	0.0250	0.0625	0.0875	0.1125	0.1375	0.0875	0.1875	0.0250	0.0375	0.0375	0.0375	0.0500
			(0.270)	(0.265)	(0.316)	(0.357)	(0.399)	(0.425)	(0.359)	(0.478)	(0.265)	(0.280)	(0.293)	(0.288)	(0.303)
3	T3 - Bird perches		0.0250	0.0500	0.0500	0.1125	0.1075	0.1250	0.0600	0.0912	0.0375	0.0375	0.0375	0.0450	0.0625
			(0.316)	(0.293)	(0.311)	(0.395)	(0.490)	(0.403)	(0.397)	(0.534)	(0.288)	(0.293)	(0.293)	(0.344)	(0.316)
4	T4 - Endosulfan 0.07%		0.0250	0.0375	0.0125	0.8750	0.0625	0.0375	0.0875	0.1500	0.0375	0.0875	0.0200	0.0250	0.0250
			(0.265)	(0.288)	(0.247)	(0.367)	(0.329)	(0.288)	(0.367)	(0.444)	(0.293)	(0.359)	(0.261)	(0.265)	(0.265)
5	T5-IPM		0.0500	0.0125	0.0250	0.1250	0.1500	0.0750	0.0500	0.1000	0.1125	0.0625	0.0000	0.0750	0.0625
			(0.293)	(0.247)	(0.270)	(0.397)	(0.521)	(0.352)	(0.303)	(0.376)	(0.380)	(0.329)	(0.223)	(0.352)	(0.326)
6	T6 - Annona leaf extract 0.05%		0.0183	0.0125	0.0125	0.0875	0.0875	0.1125	0.0750	0.0750	0.1000	0.0875	0.0250	0.0125	0.1000
			(0.280)	(0.247)	(0.247)	(0.370)	(0.351)	(0.402)	(0.352)	(0.349)	(0.385)	(0.359)	(0.269)	(0.247)	(0.380)
7	T7 - Control		0.0125	0.0500	0.0700	0.1875	0.2625	0.1500	0.1375	0.2375	0.1500	0.1375	0.1125	0.1000	0.1625
			(0.247)	(0.311)	(0.247)	(0.434)	(0.544)	(0.440)	(0.432)	(0.524)	(0.445)	(0.367)	(0.247)	(0.357)	(0.450)
	Standard error difference		0.069	0.058	0.048	0.084	0.093	0.069	0.064	0.094	0.066	0.06	0.031	0.067	0.083
	Least significant difference		0.184	0.121	0.101	0.178	0.195	0.145	0.135	0.199	0.14	0.127	0.166	0.141	0.174

Figures in parentheses are square root transformed
Significant at 5% level (P=0.05)

6

FIG.11 EFFICACY OF DIFFERENT TREATMENTS AGAINST LARGE SIZED (V & VI INSTAR) LARVAE OF HELICOVERPA ARMIGERA IN CHICKPEA



T2-NPV 250LE /Ha
T3-Bird Perches
T4-Endosulphon 0.07%
T5-IPM
T6-Annona Leaf Extract 0.05%
T7-Control

41

4.3.4 Efficacy of different treatments against total larval population of *Helicoverpa armigera:*

In order to access the efficacy of different treatments against the larval population of the gram pod borer, *Helicoverpa armigera*, the results of the experiments conducted were elucidated in table7 and fig12. The data revealed that there was no significant difference between the treatmental plots, when the counts were made before imposing the treatments on 45 DAS.

The total larval population of *Helicoverpa armigera* were significantly controlled by all the treatments that were tested. Endosulfan treatment emerged as a superior treatment, which resulted in 37 per cent reduction in the pest population, over control. NPV treatment was effective in decreasing the overall larval population by 27 percent, which was on par with IPM (30 per cent) and Annona spray (25 per cent) respectively. Neem spray reduced the pest by 22 per cent followed by the bird perches 21 per cent.

4.3.5 Effect of various plant protection options on the pod damage caused by *Helicoverpa armigera:*

A perusal of the data in Table 8 reveals that endosulfan was the best treatment, recording the lowest pod damage (20.5), which is about 50 per cent reduction over control, followed by IPM and annona spray, which were on par registering 44.4 and 44 percent reduction in pod damage over control. Neem spray stood next to HNPV spray, though with a merge margin, recorded a 35.1 percent reduction over control. The bird perches were efficient in attracting many insectivorous birds. This can be viewed from the reduction in pod damage by 31.05% over control. Though endosulfan spray recorded very low pod damage, IPM and annona were also significant in reducing the borer damage. The control plot recorded a highest pod damage of 40.7%.

4.3.6 Effect of different plant protection strategies on the grain yield of chickpea:

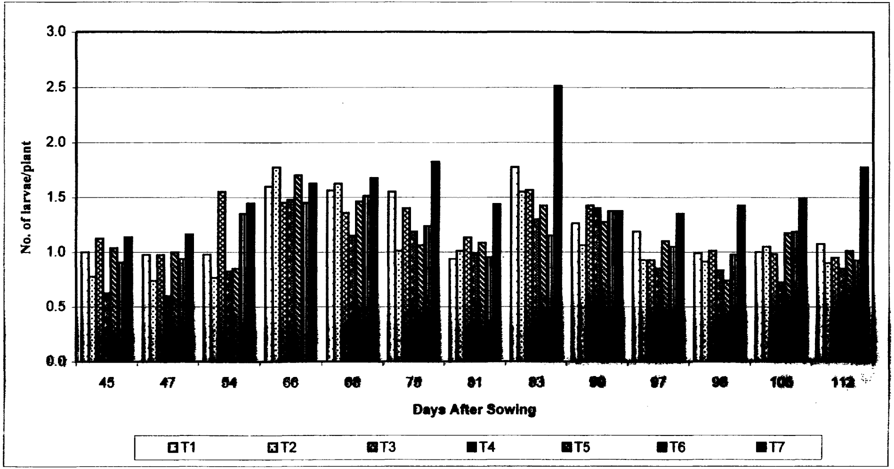
To assess the efficacy of different treatments on the grain yield of chickpea, the results of the experiments conducted are elucidated in Table 9.

Table 7 . Efficacy of different treatments against the gram pod borer (*Helicoverpa armigera) larvae.*

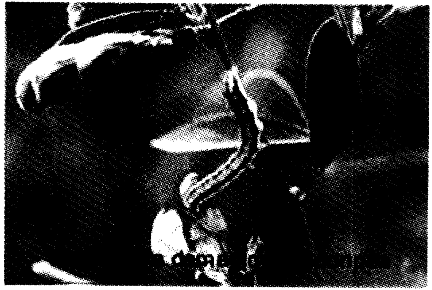
Sl. No	Treatment	DAS / DAT	Number of larvae per plant												
		DAS	45	47	54	66	68	75	81	83	90	97	98	105	112
		DAT	Pre T	1	6	18	1	7	13	1	7	14	1	7	14
1	T1 - Neem - 1500 EC		1.000	0.975	0.977	1.600	1.562	1.550	0.937	1.775	1.262	1.187	0.987	1.000	1.075
			(1.024)	(1.011)	(1 314)	(1 281)	(1.260)	(1.258)	(0.984)	(1.339)	(1.133)	(1.106)	(1.016)	(1.023)	(1.042)
2	T2 - NPV 250 LE ha^{-1}		0.775	0.737	0.765	1 775	1.625	1.012	1.012	1.550	1.062	0.925	0.912	1.050	0.900
			(0.903)	(0.870)	(1.114)	(1 336)	(1.292)	(1.030)	(1.027)	(1.264)	(1.053)	(0.980)	(0.981)	(1.042)	(0.973)
3	T3 - Bird perches		1.124	0.975	1.550	1.450	1.357	1.400	1 135	1.566	1.425	0.925	1.012	0.982	0.950
			(1.095)	(1.010)	(1.261)	(1.221)	(1.217)	(1.200)	(1.110)	(1.337)	(1.209)	(0.976)	(1.029)	(1.028)	(0.995)
4	T4 - Endosulfan 0.07%		0.625	0.600	0.825	1.475	1.150	1.187	0.987	1.300	1.400	0.850	0.832	0.725	0.850
			(0.814)	(0.804)	(0.931)	(1.230)	(1.093)	(1.108)	(1.015)	(1.161)	(1.192)	(0.932)	(0.938)	(0.879)	(0.943)
5	T5-IPM		1.037	1.000	0.850	1.700	1.462	1.062	1.087	1.425	1.275	1.100	0.737	1.175	1.012
			(1.042)	(1.024)	(1.089)	(1.315)	(1.266)	(1.046)	(1.062)	(1.209)	(1.143)	(1.071)	(0.877)	(1.101)	(1.023)
6	T6 - Annona leaf extract 0.05%		0.906	0.937	1.349	1.450	1.512	1.237	0.950	1.150	1.375	1.050	0.975	1.187	0.925
			(0.224)	(0.989)	(1.267)	(1.219)	(1.230)	(1.131)	(0.980)	[illegible]	(1.180)	[illegible]	(1.006)	[illegible]	[illegible]
7	T7 - Control		1.137	1.162	1.445	1.625	1.675	1.626	1.437	2.512	1.375	[illegible]	1.425	[illegible]	1.775
			(1.065)	(1.060)	(1.190)	(1.291)	(1.302)	(1.214)	(1.219)	(1.500)	(1.182)	(1.158)	[illegible]	[illegible]	[illegible]
	Standard error difference		0.061	0.077	0.106	0.098	0.122	0.084	0.08	0.091	0.103	0.083	0.069	0.073	0.106
	Least significant difference		0.129	0.162	0.223	0.206	0.257	0.176	0.168	0 193	0.216	0.175	0.146	0.154	0.227

Figures in parentheses are square root transformed
Significant at 5% level (P=0.05)

FIG.12 EFFICACY OF DIFFERENT TREATMENTS AGAINST THE TOTAL LARVAL POPULATION OF *HELICOVERPA ARMIGERA* ON CHICKPEA



T1-Neem 1500 EC
T2-NPV 250LE /Ha
T3-Bird Perches
T4-Endosulphon 0.07%
T5-IPM
T6-Annona Leaf Extract 0.05%
T7-Control



Damage caused by Helicoverpa armigera

Table 8 . Effect of various plant protection options on the pod damage caused by *Helicoverpa armigera* on chickpea.

Sl. No.	Treatment	Percentage pod damage	Percentage reduction over control
1	T1 - Neem - 1500 EC	26.4 (30.88)	35.08
2	T2 - NPV 250 LE ha^{-1}	26.3 (30.84)	35.2
3	T3 - Bird perches	28 (31.98)	31.05
4	T4 - Endosulfan 0.07%	20.5 (26.63)	49.64
5	T5-IPM	22.6 (28.36)	44.38
6	T6 - Annona leaf extract 0.05%	22.8 (28.47)	43.99
7	T7 - Control	40.7 (39.64)	*
	Standard error difference	1.88	
	Least significant difference	3.95	

Figures in parentheses arcsin transformed
Significant at 5% level (P=0.05)

Table 9. Effect of different plant protection strategies on grain yield of chickpea.

Sl. No.	Treatments	Grain yield (kg /ha)	Percentage increase over control
1	T1 - Neem - 1500 EC	1298	51.9
2	T2 - NPV 250 LE ha^{-1}	1317	54.2
3	T3 - Bird perches	1096	28.3
4	T4 - Endosulfan 0.07%	1392	63.1
5	T5-IPM	1361	59.4
6	T6 - Annona leaf extract 0.05%	1353	58.4
7	T7 - Control	854	*
	Standard error difference	34.5	
	Least significant difference	72.4	

Figures in parentheses arc sin transformed
Significant at 5% level (P=0.05)

The result clearly shows the dominance of endosulfan spray, which recorded 13.9 q ha^{-1}, which is about 63.11 percent increase over control (8.5 q ha^{-1}). IPM (13.6 q ha^{-1}), HNPV (13.1 q ha^{-1}) and neem (12.9 q ha^{-1}) were found to be significantly effective and on par with each other, which recorded an increase of 54.22 and 51.99 per cent grain yield over control respectively.

Although the plots with bird perches recorded, comparatively less yield (10.96), it was found to enhance the yield by 28.33 per cent when compared to control plots.

4.3.7 Economics of different treatments in the management of *Helicoverpa armigera*:

Cost-benefit ratios were worked out to know the economics of different treatments and were presented in Table 10. The results reveals that IPM was the most economical treatment registering the higher cost-benefit ratio of 1:9. Endosulfan spray stood next to IPM with a cost-benefit ratio of 1:8.7.Neem spray recorded a benefit ratio of 1:7.5. Lowest cost-benefit ratio was of NPV spray (1:6.5). An extra income of Rs.5925.00 was obtained by investing on endosulfan spray. By integrating the management practices, there was an extra income of Rs.5180.00, which was on par with the endosulfan spray.

4.3.8 Fluctuation of *Helicoverpa armigera* pest population during post-rainy 1999-2000 at ICRISAT Patancheru location:

Studies on fluctuation of *H.armigera* were carried out with a view to find the peak moth emergence and emergence of subsequent larval generation in relation to the age of the crop.

A perusal of the data in Table 11 and fig 13 shows a clear peaks in the adult population, monitored by 3 pheromone traps placed around the field, and the larval population in the chickpea field. The larval population that were recorded at weakly intervals from 45 DAS showed a gradual increase, reaching a peak at 66 DAS (1.58 larvae $^{-1}$ weak $^{-1}$), which represent the first generation of the pest, during the peak flowering stage of the crop. The end of the first generation larval population coincided with a peak in the adult population

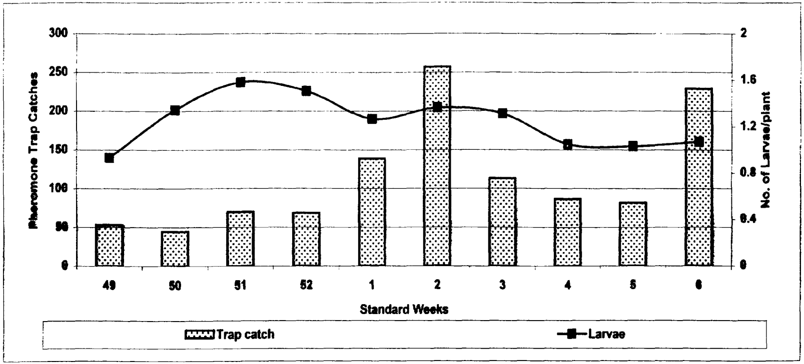
Table 10 . Cost - Benefit Ratio of different treatments against *Helicoverpa armigera* management *in* chickpea.

Sl. No.	Treatments	Grain yield (kg/ha) Gross	Grain yield (kg/ha) Extra yield over control	Gross Income (Rs.)	Cost Of Insecticidal Application (Rs.)	Total income (Rs)	C : B Cost-Benefit Ratio
1	Neem - 1500 EC	1298	444	19470	2297	17173	01:07.5
2	NPV 250 LE ha^{-1}	1317	463	19756	2645	17111	01:06.5
3	Bird perches	1096	242	16440	*	16440	*
4	Endosulfan 0.07%	1392	539	20894	2159	18735	01:08.7
5	IPM	1361	508	20426	2025	17990	01:08.9
6	Annona leaf extract 0.05%	1353	499	20296	*	19982	*
7	Control	854	*	12810	*	12810	*

Table 11. Fluctuation of *Helicoverpa armigera* pest population during the cropping season 1999-2000.

Standard weeks	Age of the crop (DAS)	Pheromone trap catches/trap/week	*H. armigera* larval population/plant
49	46	53	0.93
50	54	44.33	1.344
51	66	69.66	1.582
52	68	68.66	1.506
1	75	138.66	1.267
2	82	257	1.362
3	90	113	1.31
4	97	86.33	1.047
5	101	81.66	1.029
6	112	229	1.069

Fig.13 Fluctuation of *Helicoverpa armigera* pest population during the cropping season 1999-2000



(257 moths trap $^{-1}$ week $^{-1}$) in the second week of January. The larval population showed a decline from 97 DAS.

DISCUSSION

Chapter V

Discussion

Helicoverpa armigera (Hubner) is a major pest in several crops including the pulse crops because of its high fecundity, multiple generation, polyphagy and migratory behaviour. In order to know its behaviour and to develop better pest management practices, present studies were carried out during post-rainy season 1999-2000 at ICRISAT, Patancheru location, Andhra Pradesh, India. The results obtained were discussed in this chapter.

5.1.1 *Helicoverpa armigera* male moth activity, influence of weather on the pheromone trap catches:

The pheromone trap catches recorded here suggest that *H.armigera* males were most active between 0200 and 0400 hr. Nocturnal observations of other species of *Heliothis* (Lingren et al., 1982) may explain this as being due to an increase in the female activity and oviposition during this period of night.

The environmental factors, temperature, relative humidity and wind velocity appear to have a marked effect on the mean percent catch in the pheromone traps. However, from this data it is not possible to determine whether there is a causal relationship between the trap performance and each environmental factor or whether the relationship is mearly coincidental. Temperature can effect the rate of pheromone emission from the septum (Caro, 1982), so that the higher the temperature, the higher is the rate of pheromone emission. This would, if all other factors remain constant, increase the size of the pheromone plume, which could have concomitant effects on the size of the trap catch. However, temperature does not appear to have influenced the pheromone - trap performance here, since the mean percentage trap catch increased with the decline in the temperature. The lower temperatures were associated with the later period of the night.

The same phenomenon was also apparent with the relationship between the catch and humidity. The catch increased as the relative humidity increased, and the relative humidity increased as the night progressed. The low wind velocities that tended to occur late during the night also appeared to favor high trap catches, with a dramatic decline in mean catch when wind velocities exceeded 11 kmph. This was again surprising as *H.armigera* flight ability and its ability to orientate towards the trap would not be impaired until the wind speed approached the flight of the insect. The flight speed of the Noctuids has been reported to be between 16 and 24 kmph. (Callahan, 1965) and hence it is unlikely that the wind velocity encountered here had any effect on the ability of *H.armigera* to orientate towards the trap. The catch response in the pheromone traps to the environmental factors, temperature, relative humidity and wind velocity appeared to be related more to the time of the night than the environmental conditions prevailed rather than to the magnitude of the conditions themselves. Hence, the mean hourly catch responses are probably coincidentally rather than causally related to the environmental conditions.

Further, the interpretation of the trap catch data is often difficult because of the confounding effects of the environment on, and the interaction between insect activity and trap performance. Analysis of the data on a short time scale (between and within nights) are confounded further by the influence of patterns of activity resulting from the changes in **'Phase'** of the insect during the night. Even under perfect environmental conditions for both activity and trap performance, trap catches may be low during the period of the night so that the behavioural phase of the insect does not correspond with the specific trap stimulus.

5.1.2 Flight pattern towards the pheromone source by male *Helicoverpa* moth: -

The studies conducted on the flight pattern and orientation of male *Helicoverpa* towards the sex pheromone source have shown that, moths fly upwind in a series of horizontal zig-zags, which decrease in aptitude as the source is approached. Field observations support these general findings (Murlis and Bettany, 1977). Some new findings in this research suggest that flight towards a sex pheromone source in *H. armigera* consists of several distinct stages with deviations from a straight upwind path taking place largely in the vertical plane, with different flight patterns and perhaps also different orientation mechanisms.

During the peak moth activity (i.e., about 0300 hrs.), some moths were seen walking on the ridge of the trap, without getting trapped in. This may be because of the wide opening between the trap tunnel and the pheromone plume. This could be overcome by reducing the gap considerably. This may help the moth get trapped in due to the collision with the walls of the trap, once it tries to get out after reaching the hanging plume. Though it may possibly reduce the pheromone olfaction for greater distances (Pawar, 1988), the active searching pattern of the male *Helicoverpa* moth may overcome it.

By comparing the observations made during both high and low wind velocities, the wind velocity is thought to play a major role in '**confusing**' the moth during the hovering and searching time, closer to the pheromone plume. It has been observed that, during high to moderate wind velocities, 80% of the moths that hovered near to the septum have been trapped. This may be due to the confusion, increase in the release rate of the pheromone (Lewis and MaCauley, 1976) and thereby increasing the active area of the trap.

5.2 Ovipositional preference of *Helicoverpa armigera* to flower color variation in pigeonpea:-

Ovipositional preference tests that were conducted to assess the influence of flower color variation in pigeonpea genotypes have shown a marked difference in the host selection behaviour of the female *Helicoverpa armigera.*

The choice tests with both yellow and red color flowers have shown a sharp preference to oviposit on yellow flowers than towards red ones. But, when the female had no choice, it laid eggs on the red color flowers, but comparatively more in number to that of the red color ones in the choice tests.

Similar ovipositional studies that were conducted on chickpea in the previous season have shown less preference of the moths to oviposit on the host plants in the green house conditions, when released into the ovipositional cages. More number of eggs were laid on the cage walls throughout the ovipositional phase of the moth. The present experiments that were conducted on pigeonpea have shown a remarkable preference of *Helicoverpa* to oviposit on the flowering buds. No single egg was seen on the cage walls. This shows the attraction of the flower color of pigeonpea and subsequent oviposition. This small clue can be used effectively used in putting pigeonpea as a trap crop in chickpea and other crops, which are prone for *Helicoverpa* damage. Since pigeonpea is attacked mostly during the flowering phase (Rao and Reddy, 1991), synchronization of the flowering periods have to be taken care to increase the trapping efficiency.

The ovipositional preference of *Helicoverpa* to oviposit on the yellow flower colored genotypes when compared to the red flower color can be efficiently used in the breeding programmes for developing *Helicoverpa* resistant varieties to incorporate into future pod borer management programmes.

There is every possibility that my findings are the results of some hidden laboratory artifact, and the ovipositional errors seen in our experimental arenas might not occur in the field. In the field, the ovipositing female would have more long distance cues for host recognition and plants growing in natural settings might emit different oviposition signals than plant twigs in a glass cage.

5.3 Management strategies of Gram pod borer, *Helicoverpa armigera* in chickpea:-

Indiscriminate use of chemical pesticides led to several effects like development of resistance, resistance and resurgence, consequently emergence of new pests and leading to health hazards. The best alternative to this and to find an eco-friendly approach, the present studies were undertaken to assess the efficacy of different treatments against the gram pod borer.

5.3.1 Efficacy of different treatments against the larval population of *H.armigera*:-

(a) Small sized larval population:-

From the overall effect of four sprays, it can be inferred that endosulfan spray was the most effective treatment, since it registered 30 percent reduction in the small sized larval population over control, followed by NPV (24) and Annona sprays (23). IPM stood next in the order of efficacy (21). Erecting bird perches was also found to have concomitant effect, with a reduction of 15 percent over control.

(b) Medium sized larval population:-

Endosulfan was adjudged as the superior treatment among others, which registered 32 percent reduction in medium sized (III and IV instar) larval population over control, followed by NPV (27) spray. Neem spray (22) was also found effective along with IPM practice (20). Annona influenced the larval population by 13 percent, which was on par with the effectiveness of bird perches (14).

(C) Large sized larval population:-

Endosulfan maintained its supremacy in managing the large sized larval population (V and VI instar larvae) of *H. armigera*; by registering 65 percent reduction over control, followed by bird perches (47). IPM was on par with the bird perches plots with a significant decrease in the larval population by 46 percent. NPV spray was found to be effective, which registered a 42 percent reductions in the pest population. Both Neem and Annona sprays registered a 32 percent and 33 percent decrease in the pest population respectively.

5.3.2 Efficacy of various plant protection options against the total larval population of *Helicoverpa armigera*:-

On the whole, the overall effect of all the four sprays (Table 7 and Fig. 12) highlighted the supremacy of Endosulfan, which recorded 37 percent reduction in total larval population over control. This may be because of the suppression of the initial stages of the larval development and subsequent reduction in the population growth. IPM recorded a significant reduction in the pest population by 30 percent, over control. In IPM, the spray schedules were fixed in such a way that the first spray of NPV was to manage the first and second instar larval population. The larvae which escaped the NPV spray were managed by giving endosulfan 0.07 percent as the second spray. The neem spray was given as the third spray to reduce the borer damage, which coincided with the pod formation stage. This neem spray have helped in reducing the pod damage due to the antifeedent effects of neem. NPV was once again given as fourth spray to manage the remaining larval population till harvest. Apart from these four sprays, the bird perches which were installed @ one perch $plot^{-1}$ helped in attracting the insectivorous birds and in managing the larval population up to a certain extent in IPM plots. This IPM schedule was found effective in managing the larval population to a great extent.

Jayaraj et al (1981) reported the significance of NPV (250 LE/ha) spray to control the gram pod borer. The observations by Sharma et al (1997) on the effectiveness of NPV on chickpea pod borer, which was comparable to the other bio-pesticides, were supporting the present study.

Annona leaf extract spray was on par with Neem spray and was observed to reduce the larval population by 25 percent. This was due to the significant reduction in both small and medium sized larvae efficiently.

Neem 1500 PPM was also found to be effective (22) in reducing the larval population because of its antifeedent effect. Even though bird perches were found to be inferior among the treatments tested, it registered 21 percent reduction in the larval population over control.

The previous studies by Thakur (1988) and Sachan et al (1993) which were done on the efficacy of Neem on the gram pod borer strengthen the present findings.

The findings of Ghode (1988) and Wightman (1993) on the high avipredation of *H. armigera* by the insectivorous birds support the present study.

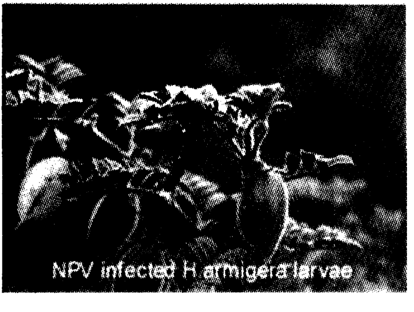
Different species of birds were observed visiting the chickpea field of which most of them were insectivorous. Almost all the birds, which were identified (Table 12), need a perch to search for the prey. The bird perches which were installed in the plots have excellently served this purpose.

Table 12 BIRDS SEEN VISITING THE CHICKPEA FIELD AT ICRISAT PATANCHERU LOCATION DURING POST-RAINY 1999-2000 - THEIR IDENTIFICATION AND HABITS :

Sl.No.	Common Name	Scientific Name	Food Habits	Remarks
1	Black Drongo / King Crow	*Dicrurus adismilis* (Bech.)	Grass hoppers and other insects , essentially needs a perch to watch and sally for the prey.	Highly beneficial to agriculture by the vast quantities of insects it destroys.
2	Roller / Blue Jay	*Coracias benghalensis* (Lin)	Large insect, frog or lizard on the ground, returning to either to the same perch or flying leisurely across to another near by.	Highly beneficial to agriculture , since it destroys vast quantities of injurious insects.
3	Cattle Egret	*Bubulcus ibis* (Lin.)	Chiefly grasshoppers, blue bottles, cicadas and catterpillars; also frogs,lizards, fish,etc.	Highly beneficial in both dry and wet agroecosystems
4	Paddy Field Pipit	*Anthus novaeseelandiae* (Lin.)	Weevils and other small insects. Runs about briskly inspurts, searching for the prey.	Mostly seen during and after ploughing in the agricultural fields.
5	Common Swallow	*Hirundo rustica* (Lin.)	Hawks winged insects high up in air or close to the ground.	Beneficial to agriculture.
6	Indian Myna	*Acridothers tristis* (Lin.)	Omnivorous. Eats fruits, insects, kitchen scraps.	Follows the plough for insects, pupae,etc.
7	Red Winged Bush Lark	*Mirafra erythroptera* (Blyth)	Seeds of grass and weeds, insects.	Beneficial to agriculture.
8	Red Wattled Lapwing	*Vanellus indicus* (Bodd.)	Insects, their eggs and larvae.	Affects open country, ploughed fields, grazing land, tanks and puddles. A beneficial bird in Natural pest control.
9	Iora	*Aegithina tiphia* (Lin.)	Insects, grubs, molluscs, etc,.	Arboreal, affects village outskirts and secondary jungle. Beneficial in agriculture and horticulture.
10	Baya Weaver Bird	*Ploceus philippinus* (Lin.)	Gleans paddy and other grain harvested fields. Also eats insects.	Seen abundantly in ICRISAT, Patancheuru campus. Beneficial in insect pest control.

Source:"**The Book Of Indian Birds**" by Salim Ali (1996 Ed.)

Cattle egrets feeding on *Helicoverpa* larvae in the chickpea field



Ecofriendly management of *Helicoverpa armigera* with Nuclear Polyhedrosis Virus

Different species of birds were seen at different timings of the day and at different crop stages. Most of the birds that were listed here were observed feeding in the chickpea field. Since all these birds were insectivorous, and no other pest except *Helicoverpa* is seen in the chickpea fields, these birds can be regarded as *Helicoverpa* predators.

The cattle egrets were seen mostly during and after the irrigation and in the shady hours of the day, while black drongos and blue jays were seen throughout the day. Paddy field pipits and common swallows were seen during and after the inter-cultivation. Some birds like shikra, bee-eaters and kingfishers were observed visiting the chickpea field, but were not seen as frequent as the birds listed in Table 12.

5.3.3 Effect of various plant protection options on the pod damage caused by *Helicoverpa armigera* :-

A perusal of the data in Table 8 revealed that Endosulfan was the best treatment by recording the lowest percentage of pod damage (20.5), which was about 50 percent reduction over control, followed by IPM and Annona spray, which registered 44 and 43 percent reduction in the pod damage over control. Neem spray was found effective and was on par with the NPV spray with 35 percent reduction in the pod damage over control (Sinha et al, 1993).

The bird perches were also found efficient in reducing the pod damage (31) due to the effective predation by the insectivorous birds. Though endosulfan recorded low pod damage, IPM and Annona were also found efficient in reducing the borer damage substantially. Annona spray, though did not show a significant reduction in the larval population, it has given a remarkable reduction in the percentage pod damage. This can be because of the antifeedent effect of the Annonin present in the leaf extract spray.

5.3.4 Effect of different plant protection strategies on the grain yield of chickpea :-

From the results (Table 9), endosulfan was adjudged as the superior among all the treatments, by recording the highest yield of 13.9 q ha^{-1}, which was about 63 percent increase over control. Due to the integration of the pest management practices, IPM was on par with the endosulfan spray, with 13.6 qha $^{-1}$. The treatments, NPV (13.1 q ha^{-1}) and neem (12.9 q ha^{-1}) were found significantly effective in increasing the yield by 54 and 52 percent grain yield over control respectively. Plots with only bird perches also recorded 28 percent increase in the yield over control mainly because of the immense bird activity at ICRISAT, Patancheru location. This 28 percent increase can be expected even in the farmer's field, if there are enough perching sites around the fields, as in the case of ICRISAT campus and can be used as one of the important tool in the IPM programme to increase the economy of the farmers.

The present studies were in accordance with the previous studies done by Thakur et al (1988), and Saxena (1980). The results of the present experiments strengthen the previous works done by Reed et al (1980) and Bhagwat et al (1997).

5.3.5 Economics of different plant protection options in the management of *Helicoverpa armigera:*

The cost-benefit ratios which were worked out (Table 10) show a higher benefit ratio(1:9)due to the integration of the management strategies(IPM). Endosulfan, which was used in the experiments were comparatively cheaper chemical and proved to be cost effective with a benefit ratio of 1:8.7, which is on par with IPM. Though the extra income of endosulfan is comparatively more than IPM, the cost Vs benefit ratio is more in IPM because of less usage of chemical, and usage of botanicals, microbials and natural enemies (birds). Due to the presence of bird perches, an extra income of Rs.3630 was obtained, which proved to be very effective and eco-friendly way to manage the pest efficiently. (Bhagawat,1997).

5.3.6 Fluctuation of *Helicoverpa armigera* pest population during post-rainy 1999-2000:

Monitoring the fluctuations in the pest population of *H.armigera* will help in knowing the vulnerable stages of the crop for the pest attack. This helps in the decisionmaking operations for better management of the pest concerned.

The *H.armigera* pest population which was monitored in the post-rainy season 1999-2000 has shown a clear peaks both in the adult and larval populations. The larval populations have shown two peaks, one at the peak flowering stage (68 DAS) and another at the podding stage (82 DAS) of the chickpea crop. Exactly three weeks after a peak in the larval population, there was an increase in the adult population. This shows the completion of the first generation, which coincided with the podding stage of the crop. A peak in the adult population was again observed in the sixth standard week, which shows the completion of the second generation of the pest.

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