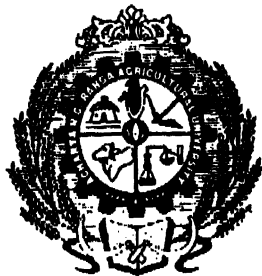


**"EFFECT OF DIFFERENT IPM COMPONENTS ON  
*Helicoverpa armigera* Hubner AND THEIR IMPACT  
ON NATURAL ENEMIES IN CHICKPEA"**

By  
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Thesis Submitted to the  
Acharya N.G. Ranga Agricultural University  
in partial fulfilment of the requirements  
for the award of the Degree of

**Doctor of Philosophy in Agriculture**



**DEPARTMENT OF ENTOMOLOGY  
AGRICULTURAL COLLEGE**

**BAPATLA - 522 101**

**June, 2001.**

## CERTIFICATE

Mr. V. Visalakshmi has satisfactorily prosecuted the course of research and that the thesis entitled "**EFFECT OF DIFFERENT IPM COMPONENTS ON *Helicoverpa armigera* Hubner AND THEIR IMPACT ON NATURAL ENEMIES IN CHICKPEA**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any university.

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## CERTIFICATE

This is to certify that the thesis entitled "Effect of different IPM components on *Helicoverpa armigera* (Hubner) and their impact on natural enemies in chickpea" submitted in partial fulfillment of the requirements for the degree of 'Doctor of philosophy' of the Acharya N G Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mrs V. Visalakshmi under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee.

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

  
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Date : 2.6.2001

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## **DECLARATION**

I, V. VISALAKSHMI, hereby declare that the thesis entitled "EFFECT OF DIFFERENT IPM COMPONENTS ON *Helicoverpa armigera* Hubner AND THEIR IMPACT ON NATURAL ENEMIES IN CHICKPEA" submitted to Acharya N.G. Ranga Agricultural University for the degree of Doctor of Philosophy in Agriculture in the major field of Entomology is the result of original research work done by me. I also declare that any material contained in the thesis has not been published earlier.

Date : 2.6.2001

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## ABSTRACT

Name of the Author : **V. VISALAKSHMI**  
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Investigations were carried out on the Effect of Different IPM Components on *Helicoverpa armigera* Hubner and their Impact on Natural Enemies in Chickpea" during *rabi* 1998-99 and 1999-2000 at ICRISAT Center. The various options of Integrated pest management (IPM) included, botanicals such as neem, insect pathogen (HaNPV), bird perches and chemical insecticides.

The pest infestation was observed throughout the cropping period in both the years with peak population during first week of January and last week of December, 1999. In both the years neem treatment effectively reduced the egg laying by *H.armigera* moths followed by IPM treatment which had neem as one of the components. During vegetative stage of the crop, endosulfan and HaNPV proved effective in reducing small and medium and large size larvae, respectively. But during the remaining period of the crop growth IPM maintained its superiority in reducing larvae of all age groups in both the years. Erecting bird perches was as effective as endosulfan in reducing large size larvae in the peak period of bird activity.

Endosulfan was observed to be a more harmful IPM component in affecting the natural enemy fauna present on ground and also on foliage of the crop. Neem also reduced the natural enemy fauna to a lesser extent. No egg parasitism by *Trichogramma* was observed in both the years though a few dead *Trichogramma* adults were observed on chickpea plants. Up to 11 and 10% natural larval parasitism by *Camponotus chlorideae* Uchida was recorded during *rabi* 1998-99 and 1999-2000 seasons, respectively. Except endosulfan all the remaining IPM components proved to be safe to *C. chlorideae*. IPM treatment was proved to be more economical than individual components except bird perches with 1:2.30 & 1:3.76 cost benefit ratio's during *rabi* 1998-99 & 1999-2000 seasons, respectively. Plots treated with endosulfan were found to have residues in seed as well as in husk even at harvest stage.

Neem proved as effective oviposition deterrent on chickpea foliage under cage studies. The antifeedant effect of neem was also proved under choice and no choice situations in laboratory. Neem produced several abnormalities in *H. armigera* like mortality during larval stage, increased larval and pupal duration, reduced pupal weight, reduced effective oviposition period and fecundity when treated at larval stages, but these effects were more pronounced on early stages of larvae than later stages. However it had no effect on egg hatchability. Robin blue 1% proved to be a good ultraviolet ray protectant and increased the persistence of HaNPV up to six days under field conditions. HaNPV was found to have more impact on early stages of larvae than later stages. In addition to high larval mortality it was found to produce several ill effects on *H. armigera* like pupal abnormality, pupal death, reduced pupal weight and reduced adult emergence. HaNPV treatment during larval stage reduced the fecundity of emerged adults up to 20% and egg hatchability up to 30%.



## INTRODUCTION

Pulses form an integral part of the vegetarian diet in the Indian sub continent. Besides being a very rich source of protein, pulses maintain soil fertility through biological nitrogen fixation by bacteria prevalent in their root nodules, thus play a vital role in sustainable agriculture. Chickpea (*Cicer arietinum* L.) is an important food legume crop in the production system of Semi Arid Tropics. Chickpea ranks second among the pulses in World. Of the 11 m. ha. of chickpea grown world wide, about 75% is grown in South Asia. India is the world's leading producer of chickpea with 68% of the total production. But the current productivity levels of pulses is low, 200-700 kg/ha. It's productivity, however is limited by a complex of interacting biotic and abiotic factors. Among biotic stresses insects are known to be the prime constraint in chickpea production throughout Asia. Of the several insect species that attack chickpea the gram pod borer *Helicoverpa armigera* Hubner is one of the major biotic constraints (Srivastava and Srivastava, 1990).

Gram pod borer is a prolific and wide spread pest, which feeds on at least 180 plant species spread across 47 botanical families (Pawar *et al.*, 1986). The biological characteristics such as high degree of polyphagy, high mobility, facultative diapause, high fecundity and multi-generation, contribute directly to the pest status of *H. armigera* (Fitt, 1989).

So far, use of insecticides has been the major approach for controlling this pest in different crops in India and in most of the developing countries. Chemical control is one of the effective and quicker methods in reducing pest population, where farmer obtains spectacular results within a short period. However over reliance and indiscriminate use

of pesticides for longer periods resulted in a series of problems, mainly risk of environmental contamination, loss of biodiversity which contributed to the development of insecticide resistant *H.armigera* population, resurgence, out breaks of the secondary pests into primary pest status, destruction of natural enemies, increase in inputs on chemicals and toxicological hazards due to pesticide residue etc., (Armes *et al.*, 1992).

Any single method of approach to pest control may not be feasible, hence the best alternative is Integrated Pest Management approach, which is based on the principles of managing the pest rather than aiming at complete eradication. In view of this, extensive studies are in progress to develop IPM combining all possible components like use of resistant varieties, cultural & mechanical control, biological suppression, chemical control, behavioural approaches etc., (Jayaraj, 1992) which 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.

A major contribution of IPM to agriculture has been to demonstrate the need to base all phases of the production system on sound ecological principles, with the ultimate goal of 'designing' agro- ecosystem that is economically and ecologically sustainable. The information available on cultural, varietal, biological and chemical methods of pest control has been critically reviewed in view of significant advances made so far in chickpea pest management strategies such as mixed or intercropping, host avoidance, use of sex pheromone traps, neem seed kernel extract and use of insect pathogen against the gram pod borer, *H.armigera* which have generated enough scope to begin with IPM in chickpea (Lal, 1992).

Heavy use of highly toxic and persistent pesticides year after year reduced the population of a potent indigenous endoparasite *Campoletis chloridae* Uchida culminating into heavy out breaks of *H.armigera* in several gram growing areas (Odak, 1982), but the availability of information on the effects of botanicals, viral pathogens and other IPM components individually and in combination on natural enemies present in chickpea crop is limited. Major obstacle in the use of insect viruses in field situations is the rapid inactivation by ultraviolet radiation (Ignoffo and Garcia, 1992). Robin blue is one of the popular UV rays protectant (Rabindra and Jayaraj, 1988), but the information on efficiency of robin blue in increasing the efficacy of HaNPV under field conditions is limited.

Hence, the present study is mainly devoted to generate information on the effect of different IPM strategies, cultural, biological and chemical, individually and in combination on the chickpea pod borer and its natural enemies, the various effects of neem and HaNPV on life cycle of *H.armigera* and the efficiency of robin blue as a UV rays protectant. The studies are contemplated with the following objectives.

1. To evaluate the effect of IPM components on *Helicoverpa armigera*.
2. To study the impact of IPM components on natural enemies in chickpea.
3. To study the effect of neem on oviposition deterrency and antifeeding activity of *Helicoverpa armigera*.
4. To evaluate the efficacy of Robin blue as UV protectant to improve the persistence of HaNPV.

## REVIEW OF LITERATURE

### ***Helicoverpa armigera* Hubner as a Pest of Chickpea**

Among seventeen species placed in *Helicoverpa*, *H.armigera*, *H.punctigera* and *H.assulta* are exhibiting higher fecundity, wide host range and greater migratory tendencies (Barrett, 1967). *H.armigera* is widely distributed from Southern Europe through Africa, Asia and Australia to the south-western pacific islands (Hardwick, 1965). About 87% of the worlds chickpea crop is grown in South Asia (Jodha and Rao, 1987) and *Helicoverpa armigera* Hubner is one of the most serious pests of grain legumes, especially chickpea and causes up to 85% pod damage in different states with an average of 8% (Sithanantham *et al.*, 1984) and up to 91.7% in Punjab (Chhabra, 1990). *H.armigera* attains peaks twice in a year i.e March-April and October (Chhabra, 1990) and the population was positively correlated with maximum and minimum temperatures and negatively correlated with Relative Humidity and % parasitism by *Campoletis chloridae* Uchida (Yadava and Lal, 1988). According to Joginder Singh *et al.* (1990) the nondiapause type of *H.armigera* completed two generations between 5<sup>th</sup> November and 5<sup>th</sup> April compared with one generation for diapausing *H.armigera*.

### **Efficacy of IPM Components Against *H.armigera***

#### **Neem**

Azadirachtin, a tetrah (or) triterpenoid is the most active insecticidal component found in neem seeds and leaves (Butterworth and Morgan, 1968). This active component has a number of biological properties including repellency, feeding and oviposition deterrency, hormone like growth disrupting activity and low mammalian toxicity (Schmutterer, 1990). Neem seed extracts or their components have systemic property and are

translocated within plants (Saxena, 1987; Morian *et al.*, 1990). Unlike ordinary insecticides based on single active ingredients, derivatives of neem comprise a complex array of novel compounds which have diverse behavioural and physiological effects on insects (Saxena, 1989). Pesticides derived from neem tree *Azadirachta indica* A. Juss. appear to be promising for use in IPM programs and provide broad spectrum control of more than 200 species of insect pests (Ascher, 1993) and safe in pest control programme and may prevent several adverse effects caused due to application of synthetic insecticides (Rajasekaran and Kumaraswamy, 1985).

Odak (1982) tested different plant products and concluded that neem seed kernel extract 5% had lowest pod damage (3.1%) due to *H.armigera* in chickpea. Neem seed kernel extract 2% and 2% hot pepper fruit extract gave good protection of bean from *Maruca testulalis* (Geyer) and *H. armigera* and other important insect pests (Hongo and Karel, 1980). Thakur *et al.*, (1988) reported that on the basis of grain yield, endosulfan 0.07% was the most effective treatment followed by monocrotophos 0.04% & neem leaf extract 5% and on the basis of profitability neem leaf extract 5% was the most effective followed by endosulfan 0.07% and monocrotophos 0.04% treatments. It was concluded that neem seed kernel extract can be used in place of highly toxic synthetic insecticides because of its safety to beneficial insects and its lower cost against *H. armigera* in chickpea. Sinha and Mehrotra (1988) reported that application of neem oil (at 375, 560, 750 & 3750 ml / ha) in chickpea field against *H. armigera* at flowering and 10 days after did not give a significant effect in reducing the larval population and the incidence of damage but gave higher yield of seed than untreated control.

According to Sehgal and Ujagir (1990) neem seed kernel extract at 5% was less effective against *H.armigera* in chickpea than endosulfan 0.07% at 100 g a.i./ha but still significantly better than the control. According to Sachan and Lal (1993) neem seed kernel extract and neem leaf extract were effective for controlling the noctuid, *H. armigera* on chickpea and pigeonpea. Datkhile *et al.* (1992) reported that neem seed extract at 5% was the least effective on gram pod borer when compared to synthetic pyrethroids. Butani and Mittal (1993) reported that malathion, DDT and neem seed kernel suspension were all equally effective in controlling *H.armigera* in chickpea and increasing grain yield. According to Sinha (1993) when infestation of *H. armigera* in chickpea reached 20.5% (1986-87) and 12.5% (1988-89) spraying with diflubenzuron (0.05%), neem oil and kernel extract 5% at an interval of 10 days gave a 2-fold reduction in infestation compared with the untreated control.

Sinha (1993) also reported that during 1989 and 1990-91 neem emulsion & neem wp gave 40-60% control. Neem kernel extract 5% gave 40% reduction in infestation of *H.armigera* in chickpea and was comparable to endosulfan 0.07% (1989-91). It was reported that there is no significant difference in the seed yield in plots treated with neem emulsion 0.125%, neem kernel extract 5%, flufenoxuron 0.01% and endosulfan 0.07% against *H. armigera* in chickpea. Sarode *et al.* (1995) reported that NPV and neem seed kernel extract gave better control of *H.armigera* on chickpea when applied in combination than when applied singly. Khan (1996) reported that neem seed extract 5% and Nimbecidine 0.2% recorded 21.9 Q/ha and 19.6 Q/ha seed yield of chickpea by reducing *H.armigera* infestation which are comparable with other treatments viz. cypermethrin + profenofos 0.088%, monocrotophos 0.04%, profenofos 0.2% and chlorpyrifos 0.05%. According to Ravi and Verma (1997)<sup>b</sup> azadirachtin was the least

effective insecticide compared to fenvalerate, endosulfan and diflubenzuron in reducing *H. armigera* in chickpea

In a laboratory study Nimbecidine gave 20.2% egg mortality of *H. armigera* whereas endosulfan gave 41.1% (Usha and Patel, 1997). Jeyakumar and Gupta (1999) noticed ovicidal effect of NSKE in different age groups of eggs of *H. armigera* and mortality decreased with increase in age group of eggs. According to Ujagir *et al.* (1997) azadirachtin (Nimbecidine 0.03%) did not show any yield increase by reducing the pod damage caused by *H. armigera* when compared to either HNPV or chemical insecticides in chickpea. Murugan *et al.* (1998) reported that the neem limonoids azadirachtin, salanin, deacetyl gedunin, 17-hydroxy azadiradione and deacetyl nimbin were found to be potent antifeedants and growth inhibitors to the cotton boll worm *H. armigera*. Padmaja and Rao (2000) recommended three plant oils including neem oil as a potential control measure for the management of the American bollworm, *H. armigera* on the basis of ED50 dose.

### HaNPV

Anita Mistry *et al.* (1984) reported that five sprays of NPV @ 250 LE / ha / week gave satisfactory control of *H. armigera* in chickpea and increased in grain yield upto 47% over control. Dhamdhare and Khaire (1986) evaluated different doses of HNPV on *Cicer arietinum* L. against *H. armigera* and concluded that two applications of 450 LE / ha at a 10 day interval were most effective in reducing the damage and resulted in the highest yield. Jayaraj *et al.* (1987) reported that *H. armigera* population in chickpea was significantly reduced with an application of 250 LE / ha HNPV and the virus was more effective when sprayed in the evening than in the morning. When the virus was applied

with 2% starch or 1% sugar there was no difference between morning and evening applications. Pawar *et al.* (1987) concluded that 2 sprays of HNPV @ 500 LE / ha were as effective as 2 sprays of 0.05% endosulfan in reducing infestation by *H. armigera* and pod damage in chickpea and in increasing seed yield. Bilapate *et al.* (1988) recorded 6.9, 1.9 and 24.5% mortality of *H. armigera* due to NPV during 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> generations, respectively.

According to Pawar *et al.* (1990) the lowest pod damage and highest yield were observed in plots treated with 2 sprays of endosulfan 0.07% or 2 sprays of HNPV @ 500 LE / ha or with one spray of HNPV @ 500 LE / ha followed by one spray of endosulfan 0.07% against *H. armigera* in chickpea. Chundurwar and Pawar (1991) described mortality of *H. armigera* infesting chickpea in Maharashtra, India due to natural infection by a nuclear polyhedrosis virus. Rabindra *et al.* (1992) evaluated the effect of HNPV on different varieties of chickpea against *H. armigera* and concluded that control of *H. armigera* on chickpea with HNPV was significant on the highly susceptible or moderately susceptible (Co 2) varieties than on the tolerant variety (ICC 506). A single spray of 250 LE / ha of HNPV in 500 litres of water per hectare resulted in 97.2% mortality of *H. armigera* in 1987 and 25.4 to 78.8% larval mortality during 1988 in chickpea (Misra *et al.*, 1991).

Elcar (HNPV) and Dipel (*B.t.*) were not as effective as cypermethrin in controlling *H. armigera* infestation in chickpea but yield was significantly high in bio-insecticidal treated plot than control and was statistically on par with cypermethrin treated plot (Ibrahim Ali *et al.*, 1993). According to Sarode *et al.* (1995) HNPV @ 500 LE / ha recorded the lowest infestation of *H. armigera* on cotton followed by NSKE 6%, hence recommended in IPM system.



NPV had greater effect on the density of *H. armigera* large larvae on susceptible chickpea genotypes than on ICC 506 variety and the yields were also significantly higher in NPV treated susceptible genotype compared to quinalphos or control plots (Cowgill and Bhagwat, 1996). Abhisek Shukla and Goydani (1996) reported that application of HNPV for the control of *H. armigera* infesting chickpea produced a significantly higher seed yield compared to control but low compared to plots treated with endosulfan. Sharma *et al.* (1997) assessed different biopesticides and chemicals for control of *H. armigera* in chickpea and concluded that HNPV gave the best control compared to other biopesticides and chemicals.

### Biological control

Achan *et al.* (1968) reported *Camponotus chlorideae* Uchida as a larval parasite of *H. armigera*. The activity of *C. chlorideae* brings an appreciable reduction of *Heliothis* larvae and crop losses in chickpea (Bhatnagar and Davies, 1978). First record of *C. chlorideae* on *H. armigera* in Bihar to the extent of 14.3 to 58% was reported by Prasad and Chand (1986). Inundative release of *Trichogramma chilonis* Ishii to control the noctuid, *H. armigera* was ineffective in gram (Yadava *et al.*, 1985). Parasitism by the ichneumonid *C. chlorideae* in *H. armigera* on chickpea was highest during December, lowest during February and almost nil during March (Yadava, 1990). The larval parasites of *H. armigera*, braconids, *Apanteles* sp., *Bracon* sp. and *Microbracon* sp., the ichneumonid, *C. chlorideae* and the eulophid *Euplectrus euplexiae* were reported by Singh and Balan (1986). Mehto *et al.* (1986) recorded eight species of natural enemies on *H. armigera* in chickpea, which included *C. chlorideae*, Araneae, *Coccinella* spp., *Chrysopa* spp and *Pantala* spp.. ICRISAT (1987) reported parasitism of *H. armigera* in chickpea by *C. chlorideae* and *Carcelia illota* Curron in Andhra Pradesh. *H. armigera* population in chickpea was

negatively correlated with per cent parasitism by *C. chloridae* (Yadava and Lal, 1988). Srinivas (1989) studied seasonal incidence of *C. chloridae* and *Eriborus* sp. on *H. armigera* in chickpea, and found peak parasitization by *C. chloridae* in first two weeks of December (43.9%) and by *Eriborus* sp. during last week of January (43.8%). Early instars of *H. armigera* were more prone to attack by various enemies (Srinivas and Jayaraj, 1989). Garg (1989) observed 25% parasitization of *H. armigera* by *C. chloridae*. Shrivastava and Yadav (1991) recorded 61.9% and 16.66% parasitization of *H. armigera* by *C. chloridae* at Kawardhe and Amora areas of Madhya Pradesh, respectively in chickpea. The ichneumonid *C. chloridae* and tachinid, *C. illota* and the braconid, *Apanteles* spp. played a key role in suppressing the larval population of *H. armigera* in chickpea during podding stage (Patnaik *et al.*, 1991; Mishra *et al.*, 1992 and Ahmed *et al.*, 1996).

A German ornithologist estimates that a single pair of tits with their progeny destroy annually at least 120 million insect eggs or 150,000 caterpillars and pupae (Ali, 1996). Ghode *et al.* (1988) observed the avian predation of gram pod borer *H. armigera* in Orissa and reported that the cattle egret (*Bubulcus ibis* Lin.) and river tern were feeding *H. armigera* on bengalgram in the third week of January. Due to the presence of the birds, the population of *H. armigera* was reduced from 5-10 larvae/plant in the middle of January to a negligible number (<1/plant) by the end of the month. Patel (1988) conducted studies on predation of *H. armigera* and *Spodoptera litura* Fab. by insectivorous birds with special emphasis on mynas *Acridotheres tristis* (Lin.). Joginder Singh *et al.* (1990) mentioned the importance of house sparrow and myna as natural enemies of *H. armigera* in Ludhiana. In Kota, Rajasthan the house sparrow reduced *Helicoverpa* population by 20 to 40% (ICAR, 1992). Wightman *et al.* (1993) suggested 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.

### Endosulfan

Daware and Dhanorkar (1981) reported that several conventional insecticides such as endosulfan, monocrotophos, quinalphos, etc were found effective against *H. armigera*. According to Dhurve and Borle (1985) permethrin 0.01% followed by carbaryl 0.2% and endosulfan 0.05% were effective in reducing the damage caused by *H. armigera* in chickpea and recorded significantly higher yields. Three sprays of 0.05% endosulfan or 0.05% quinalphos at 15 day intervals commencing at 50% flowering stage gave most effective and economic control of *H. armigera* in chickpea (Rizvi *et al.*, 1986)

Jayaraj *et al.* (1987) compared efficiency of NPV, endosulfan and its combination in controlling *H. armigera* in chickpea and reported that mixture of NPV (125 LE / ha) and endosulfan (0.035%) resulted in maximum protection. But an application of virus @ 250 LE / ha followed by endosulfan 0.035% five days later was on par with 0.07% endosulfan. Two sprays of HNPV @ 500 LE / ha were as effective as two sprays of 0.05% endosulfan in reducing infestation by *H. armigera* larvae and pod damage and increased yield in chickpea (Pawar *et al.*, 1987). Gunasekaran and Balasubramanian (1987) reported that endosulfan @ 525 g a.i. / ha resulted in reduction of 75.2, 87.6 & 98.2% of *H. armigera* at 1, 3 and 7 days after application on chickpea. Sanap and Deshmukh (1987) tested seven insecticides for the control of *H. armigera* on chickpea, among which 0.07% endosulfan resulted in the least pod damage (1.4%) and highest yield (1209 Kg / ha). According to Thakur *et al.* (1988) on the basis of grain yield and profitability endosulfan at 0.07% was the most effective treatment in

controlling *H. armigera* on gram followed by monocrotophos at 0.04% and neem kernel extract at 5%. On the basis of mean per cent damage at the dry pod stage and grain yield, fenvalerate 0.02% and endosulfan 0.07% were the most effective treatments against *H. armigera* on gram (Kaul *et al.*, 1988). Among various insecticides tested endosulfan 0.07% spray gave maximum protection against *H. armigera* in standing crop of bengalgram (Jain and Singh, 1988). Parsai *et al.* (1989) tested eleven insecticides against *H. armigera* on chickpea and reported that 0.05% monocrotophos and 0.07% endosulfan were highly effective. One spray with endosulfan at flower bud formation to reduce *H. armigera* on chickpea achieved 61.1 to 81.1 % mean reduction of larvae at different locations and 60.0 to 87.5% avoidable loss in grain yield (Singla *et al.*, 1989). According to Deka *et al.* (1989) endosulfan at 500 g a.i. / ha was the most effective of five insecticides tested in reducing larval population of *H. armigera* by 94.4% at 72 hrs after spraying and in obtaining yield increase of 159.03% compared to untreated control in *C. arretinum*. Endosulfan spray gave good control of *H. armigera* in chickpea (Ghosh *et al.*, 1989).

Sehgal and Ujagir (1990) reported that endosulfan at 420 g a.i. / ha significantly and consistently reduced pod damage by *Helicoverpa* to < 22.5% from 65.5% and increased grain yields to > 1.7 t / ha from 0.7 t / ha in chickpea and not shown any phytotoxic effect when applied during flowering stage (Parsai *et al.*, 1990). Endosulfan 0.07% followed by 0.06% endosulfan were the most effective treatments against *H. armigera* in chickpea (Gupta *et al.*, 1990). The lowest pod damage due to *H. armigera* (3.8%) and highest yield (1379 Kg / ha) were observed in plots treated with 2 sprays of endosulfan in chickpea. According to Gupta and Thakur (1990) monocrotophos 0.05%, fenvalerate 0.01% and endosulfan 0.08% gave good control of *H. armigera* larvae in chickpea and increased yield by

67–70% in November sown crop and by 103 – 113% in December sown crop. ULV spray of endosulfan @ 1 l / ha in bengalgram reduced *H. armigera* to 4.40 larvae / 5 plants and 12.61% pod damage. Patel *et al* (1990) recommended one spraying of monocrotophos 0.04% at 50% flowering followed by endosulfan 0.07% 15 days later for irrigated chickpea

According to Barkhade *et al.* (1991) pod damage due to *H. armigera* on chickpea was the least with 4% endosulfan dusting at 30 days after flowering but spraying with 0.05% endosulfan at 10 DAF, dusting with 4% dust at initiation of flowering and 2 sprays of 0.05% endosulfan at 15 and 30 DAF gave similar effect. Greatest yields were obtained on different cultivars of chickpea treated with two applications of endosulfan 0.07% during the pod formation stage (Chauhan and Dahiya, 1991). According to Gupta *et al.* (1991) among different spray schedules sequential spraying at the flowering followed by podding stage with endosulfan 0.07% is the most effective in terms of cost : benefit ratio, 12 : 1 in chickpea. Khan *et al* (1993) tested different insecticides against noctuid *H. armigera* on gram, applied at pod formation and at 15 days later and concluded that endosulfan and cyfluthrin were most effective while endosulfan recorded the highest average yield of 32 Kg / plot compared to untreated control. According to Sinha (1993) NSKE 5% was comparable to endosulfan 0.07% against *H. armigera* in chickpea during 1989-90, where as endosulfan 0.07% gave 72% control during 1990-91. In a laboratory study endosulfan 0.07% gave 100% inhibition of *H. armigera* egg hatching (Mala *et al.*, 1993).

Two applications of endosulfan against the gram pod borer on *C. arietinum* recorded average larval population of 0.88 per plant as against 2.6 in control and yield was 1573 Kg / ha against 251 Kg / ha in no treatment (Noorani *et al.*, 1994). Two sprays of endosulfan at 50%

flowering followed by 2 sprays at the green pod stage effectively controlled *H.armigera* on chickpea (Giraddi *et al.*,1994). Endosulfan 0.07% significantly reduced *H armigera* in chickpea and recorded the highest grain yield irrespective of sowing dates (Chaudhary and Sachan, 1995) According to Vyas and Lakhchaura (1996) endosulfan 0.07% applied twice was superior compared to monocrotophos and HNPV in controlling *H armigera* on chickpea.

### IPM

In the past 30 years the fundamental paradigm that emerged in plant protection is IPM. A major contribution of IPM to agriculture has been to demonstrate the need to basic all phases of the production system on sound ecological principles, with the ultimate goal of designing agroecosystems that are economically and ecologically sustainable. During the last two decades considerable amount of work has been carried out on the use of parasitoids (Nagarkatti, 1982), predators (Greathead and Girling, 1982; King *et al.*,1982), microbial insecticides including nuclear polyhedrosis virus (Tinsley, 1979; Bell, 1982; Mc Kinley, 1982) and neem extracts (Thakur *et al.*, 1988; Rao *et al.*, 1990) in pest management. However no single method of control can be expected to provide an acceptable solution to pest management. The discipline of integrated pest management (IPM) has been built on the philosophy of total system consideration and multiple control techniques.

Reed and Pawar (1982) reviewed the management strategies and approaches to manage *H.armigera* on chickpea which covered population studies through pheromone and light traps, use of insecticides, NPV, parasitoids, cultural practices and breeding for host plant resistance. Pawar *et al.* (1987) reported that population of *H.armigera* in chickpea is

the lowest in plots which received two applications of 0.05% endosulfan followed by those treated with virus only @ 500 LE / ha and a treatment in which application of 500 and 250 LE / ha were followed by endosulfan 0.05% sprays. According to Jayaraj *et al.* (1987) an application of HNPV @ 250 LE / ha followed by endosulfan 0.035% 5 days later was on par with 0.07% endosulfan for the control of *H.armigera* on chickpea. None of the various IPM components like natural enemies including *C. chloridae*, NPV, inter-cropping system and altering sowing dates were superior to recommended pesticides in controlling *H.armigera* on chickpea and pigeonpea (Mahajan *et al.*, 1990). Pawar *et al.* (1990) observed the lowest pod damage of, 3.84% and highest yield of, 1379 Kg / ha of chickpea in plots treated with 2 sprays of endosulfan 0.05% alone or NPV @ 500 LE / ha or one spray of NPV @ 500 LE / ha followed by one spray of endosulfan 0.05%. Six years of experimentation revealed that NPV + two sprays of endosulfan (0.035%) at 1<sup>st</sup> and 3<sup>rd</sup> week of the crop recorded less pod damage and maximum yield against *H.armigera* in chickpea (Thakur, 1990).

Pimbert (1990) reported the themes that call for more research attention for IPM of *H. armigera* in chickpea like host plant resistance and G x E interaction, vegetation management and biological control, IPM and the selective use of plant diversity, biotechnology and pest control, group action to complement pest controls aimed at individual house holds and sustainability. Ahmed *et al.* (1990), Weigand & Tahhan (1990) and Sithanantham (1987) reviewed various aspects of *H.armigera* management on chickpea and also covered population studies through pheromone traps, insecticide use, use of bacteria, viruses and parasitoids, cultural practices and host plant resistance and breeding and integration of control methods. According to King and Sawicki (1990) all the IPM desiderata of increased

use of resistant or tolerant cultivars, timely pesticide applications targeted against neonate larvae based on scouting and economic thresholds and rotation of insecticides especially the synthetic pyrethroids can be used for *H. armigera* resistance management. ICRISAT, AICRIP and Directorate of Pulses Research conducted surveys and given overview of the biological and ecological aspects of the *H. armigera* in chickpea and pigeonpea and pest control measures which include use of pheromone traps, parasitoids (*C. chloridae*), predators (*Delta* spp.) and HNPV, breeding for HPR, advancing the sowing date or using early maturing varieties, mixed or intercropping with cereal / other legumes, use of phosphate fertilizers and application of insecticides (Sachan, 1990). According to Lal (1990) and Yadava (1990) *H. armigera* is an important pest of chickpea and pigeonpea in U.P, India. Use of insecticides, NSKE, pheromone traps, growing early maturing cultivars or advancing the sowing date, opting for resistant varieties, use of parasitoids and pathogens (NPV) were considered effective in controlling this pest in this state.

Sachan and Lal (1993) reported that use of 250-375 LE/ha NPV alone or in combination with endosulfan 0.035% has given 60-80% and NSKE at 5% has given 50-70% mortality of *H. armigera* in chickpea. According to Jayaraj (1992) excessive reliance on chemical control method alone for the effective management of *H. armigera* has led to several problems and reported that the use of NPV in combination with Jaggery, teepol, etc., pheromone and light traps for monitoring, inundative release of parasites, application of NSKE 5% were good for control of *H. armigera* in pulses. Sarode *et al.* (1995) reported that application of HNPV @ 500 LE/ha plus the neem extract at 6% gave the maximum reduction in *H. armigera* larval number than when applied singly in chickpea crop. Three insecticidal



applications during the season based on thresholds in an on-farm chickpea fields in susceptible (Annegiri & ICC 37) and resistant (ICC 506) varieties resulted in a threefold increase in yield (Wightman *et al.*, 1995)

According to Sarode and Sarnaik (1996) *H.armigera* damage caused during flowering and podding stage results in substantial losses i.e about 30 – 100% avoidable yield loss and also reported that adverse effects of chemical control led to switch onto the IPM programme, in which HNPV and NSKE were found to be effective, the addition of half doses of insecticides to these have been reported to improve their efficiency

Yadava (1996) conducted chickpea onfarm trials in Nepal during 1992-95 and compared improved agronomic package i.e., seed treatment with thiram + bavistin, hand weeding at 25 DAS and spraying Thiodan or Decis against *Heliothis* with farmers practices and reported high yield by 16–87% and significantly increased net returns. Sanap and Pawar (1998) conducted a field experiment in Maharashtra during 1993–96 for controlling *H.armigera* infesting gram. IPM treatment comprising endosulfan 0.07%, NSKE 5% and NPV @ 250 LE / ha were evaluated, and the results revealed that 3 spray applications starting from initiation of flowering and subsequent 2 sprays at 15 days interval with first 2 sprays either with NPV or NSKE followed by a 3<sup>rd</sup> spray with endosulfan were the most effective and resulted in a 26.9% and 27.3% increase in yield, respectively. According to Prasad and Singh (1997) chickpea sown on 25<sup>th</sup> September produced more grain yield and had a lower incidence of *H.armigera* compared to sowing on 10<sup>th</sup> October. According to Bhagwat (1997) an integrated pest management strategy using a botanical insecticide, host specific virus to protect chickpea from pod borer showed better efficacy of the approach over local farmers practices in onfarm situations.

The integrated pest management components *T.chilonis*, *Chrysoperla carnea* Stephens, HNPV, Nimbecidine, Dipel and synthetic chemicals were imposed at different interval on the basis of pheromone trap threshold level on a consolidated block of 40 ha cotton fields at two locations, Shankaraband and Kurlagundi. The results demonstrated a significant superiority of the IPM strategy in terms of both cost versus benefit and environmental safety over that used in the farmers fields where only conventional control methods were followed (Reddy and Manjunatha, 2000)

### **Effect of IPM Components on Natural Enemies**

#### **Neem**

Parmar (1993) recommended use of neem in IPM as it was found relatively safe to natural enemies. Li *et al.* (1986) tested 29 insecticides including *B.t* and neem oil in order to study their side effects on *Trichogramma japonicum* Ashmead and concluded that neem oil and *B.t* were the safest pesticides for the parasitoid. Aqueous NSKE 2% had no influence on oviposition of the egg parasitoid *Telenomus remus* Nixon (Joshi *et al.*, 1982). Neem products showed little affect on *T.chilonis* (Malathi *et al.*, 1999). Markandeya and Diwakar (1999) reported that when *H.armigera* eggs were treated with Margosan 1500 ppm 10 ml/l, *T. chilonis* parasitised 45% eggs as compared to 97.4% in control but not affected hatching. Neem seed oil at 0.3% deterred oviposition (parasitization) by the parasitoid *T.chilonis* (Raguraman and Singh, 1999). Spraying of high concentration of AZT-VR-K on adult braconids and their contact with sprayed cabbage leaves for 2 days has no obvious effect on the wasps (Schmutterer, 1992). Cano and Gladstone (1994) studied the influence of the NSK based extract NIM-20 on parasitization of eggs of the *H.zea* in a melon field by *T. pretiosum* and concluded no negative effect.

Neem oil was the safest pesticide for spiders, mainly *Lycosa pseudoannulata* (Bosenberg & Strand) as compared with three synthetic products (Wu, 1986) and in comparison with endosulfan (Fernandez *et al.*, 1992). Serra (1992) also did not observe any adverse effects of a 4% aqueous NSKE on unidentified spiders in tomato fields. The commercial products Margosan-O™, Azatin™ and RD9 Repellin showed no toxicity to the spider fauna (Mansour *et al.*, 1993). Breethaupt (1995) in corn fields and Saucke (1995) in cabbage fields reported no harmful effects to spider *Oxyopes papuanus* when NSKE 2% or Neem Azal-S applied. Markandeya and Diwakar (1999) also reported that Margosan, a neem product did not affect the survival of wolf spider, *Lycosa pseudoannulata*. Feeding of the adults of the earwig *Doru taeniatum* using larvae of *Spodoptera frugiperda* (S. & A.) confined for 2-4 days on corn leaves treated with AZT-VR-K a neem product, did not cause mortality of the predators (Hellpap, 1985). The cricket *Metioche vittaticollis* was not affected by neem seed bitters containing Aza and other active ingredients at 10,000 ppm in field trial (Lamb and Saxena, 1988). According to Fernandez *et al.* (1992) in a trial with 3% neem oil, 5% aqueous NSKE, endosulfan and water as control, all the mirid bugs died in endosulfan treatment but no mortality was recorded in the other treatments.

In a laboratory experiment, adults of the coccinellid, kept on neem oil treated glass plates according to IOBC/WPRS guidelines did not show increased mortality or reduction of fecundity when compared to control, but metamorphosis of the larvae was interrupted (Schmutterer, 1981). Predaceous coccinellids survived when a formulation with high neem oil content was sprayed whereas the target pest, sorghum aphid was successfully controlled (Srivastava and Parmar, 1985). Treatment with Neemix 4.5 EC caused several abnormalities throughout the life cycle and

even in emerged adults also in *C. septempunctata* treated at immature stages but the LC50 values were much higher than recommended rate for pest control. hence can be safely used in IPM programmes (Banken and Stark, 1997 and 1998) Maragosom 1500 ppm 10 ml / l gave 6.7 and 5% mortality due to contact to grubs and adults of *Menochilus sexmaculatus* (Fabricius) (Markandeya and Diwakar, 1999).

Eisenlohr *et al* (1992) reported that the number of syrphid larvae was not reduced in the field after spraying with Neem Azal – F on peach trees infested by *Myzus persicae* (Sulzer), but the number of adults derived from larvae collected in the field on treated trees were reduced. Isman *et al* (1992) showed that neem had no detrimental effects on predatory syrphids. Lowery and Isman (1995) reported that the number of larvae of predacious cecidomyiids was reduced in the field after application of NSKE 14% and neem oil 1% as compared with control.

AZT-VR-K 1000 ppm (Kaethner, 1991) and Neem Azal – F (Vogt, 1993) did not show any side effects on the broad spectrum predator *C. carnea*. Schulz *et al.* (1997) indicated no negative effects of Neem Azal-T/S @ 3 l / ha on *C. carnea* and to honey bees. According to Srinivas and Sundara Babu (2000) various neem products caused egg and grub mortality of *C. carnea* and also affected longevity of adults.

Margosan – O proved to be nontoxic to honey bee workers up to a concentration of 4418 ppm AZ / ha (Schmutterer and Holst, 1987). Honey bee larvae are less susceptible to azadirachtin than most pest species (Neumann and Isman, 1996).

## HaNPV

A parasite *C chlorideae* was found to transmit the NPV virus both directly (100%) and indirectly (50%) (Odak *et al.*, 1982). Bijur *et al.* (1991) reported that *Apis cerana indica* did not show any signs of abnormal development when treated with NPV of *H. armigera*. Ruberson *et al.* (1991) found that a nabid predator *Nabis raseipennis* Reuter fed with NPV infected soybean looper larvae did not affect survival rate but had a shorter developmental time than those fed with healthy prey. Heinz *et al.* (1995) indicated that two common predators *C carnea* and *Orus insidiosus* were not adversely affected by feeding on larvae of *Heliothis virescens* infected with recombinant *Autographa californica* (Speyer) NPV. Sajap *et al.* (1999) reported that when an assassin bug *Sycanus leucomesus* Walk was fed on NPV infected larvae of *S. litura*, it appeared normal but with smaller size of head capsule & shorter tibial lengths with 10% reduced survival, 12 days prolonged pre-oviposition period, reduced longevity and fecundity of adults.

## Endosulfan

In a laboratory study spraying of endosulfan 0.07%, monocrotophos 0.05%, phosalone 0.1% on *Trichogramma* parasitized eggs of *H. armigera*, the emergence of adult parasitoids were not affected (Santharam and Kumaraswami, 1985). Malathi *et al.* (1999) reported that endosulfan was relatively toxic on emergence of *T. chilonis*, oviposition behaviour but not on the further development. Heavy use of highly toxic and persistent pesticides year after year reduced the population of a potent indigenous endoparasite *C. chlorideae* culminating into heavy out breaks of *H. armigera* in several gram growing districts of Madhya Pradesh (Odak, 1982). Pawar *et al.* (1989) reported that the parasitism by *C. chlorideae* was lower in pesticide treated area compared to untreated control. Ravi and Verma (1997)<sup>b</sup>

recommended endosulfan for the control of *H. armigera* which showed little effect on the larval parasitoid *C. chloridae*. Krishnamoorthy (1995) reported that endosulfan, dicofol, monocrotophos, phosalone, methyl demeton, phosphamidon, dimethoate, sulphur and dithane M-45, were found toxic to both larvae and adults of *C. carnea* in a laboratory study. Both spider and ground beetle populations were known to be reduced by regular application of insecticides (Pfrimmer, 1964; Luff, 1987). Pyrethroid insecticides suppressed web building frequency and web size and building accuracy of spider *Aroneus diadematus* (Samu and Vollrath, 1992). Some group of invertebrates such as ground beetles (Carabidae) and spring tails (Collembola) had decreased substantially and persistently under the high input (prophylactic) pesticide regime (Cilgi *et al.*, 1993). Kostandy (1995) reported that the population density of the predators decreased obviously in the fields treated with insecticides for controlling cotton bollworms. Frequent use of fungicides and insecticides reduced the abundance, activity and species diversity of spiders (Rayner *et al.*, 1996). Endosulfan (367.5 g a.i. / ha) and dimethoate (120 g a.i. / ha) caused less reduction of theridiid spider and lacewing larvae, several coccinellids and Hemiptera compared to thiodicarb and methomyl (Wilson *et al.*, 1998). According to Van den Berg *et al.* (1998) natural enemies generally have a high impact on Lepidoptera in unsprayed fields in Indonesia, but generalist predators seem to recover more slowly after insecticidal application than lepidopterans leads to more dependency on insecticides for the control.

## Residues

Pandey *et al.* (1977)<sup>b</sup> with two sprays of 0.07% endosulfan at 600 l. / ha on bengalgram at pod formation stage for the control of the pod borer, observed that its residues were much higher than the tolerance limit even 25 days after spraying both on the plant and in the grain. Pandey

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*et al* (1977)\* with two sprays of 0.07% endosulfan at 500 l / ha to pea crop at the pod formation stage, recorded 5.90 ppm residue at the time of harvest in the plant. There was an increase in the residues in the grain from 1.95 to 3.30 ppm starting from 3<sup>rd</sup> to 15<sup>th</sup> day after first application which was attributed to the translocation and accumulation of the toxicant in the grain. 3.3 ppm of residue recorded in the grain at the time of harvest.

Verma (1983) studied the persistence of carbaryl, endosulfan, monocrotophos and chlorfenvinphos applied for control of pest complex of bengalgram and reported that endosulfan residue fell below the tolerance limit in 12 days and residues were persistent in leaves than in pods. Gopal *et al.* (1988) analyzed the residue of stereo isomers of endosulfan and its toxic metabolites by GLC when applied at 0.07 and 0.14% and reported that the residue did not exceed the maximum tolerance level on the edible plant parts of brinjal and gram at the time of harvest. According to Singh *et al.* (1988) when endosulfan was applied @ 0.5 Kg a.i. / ha on sorghum, the initial deposit was 3.14 ppm this degraded to 1.17 ppm (below tolerance limit of 2ppm) within 5 days and fell below the detectable level after 20 days. The half life of endosulfan in sorghum was 11.95 days.

Singh *et al.* (1990) reported residues in soybean crop as 0.137, 0.913 and 1.947 ppm when treated with 0.05, 0.1 and 0.2% concentrations of endosulfan 8 days after treatment, but at the time of harvest the residue was below detectable limit both in grain and haulms. According to Parihar *et al.* (1990) in Jaipur, Rajasthan, waiting periods of 1.3 and 2.33 days should be observed before the green pods of chickpea can be consumed safely after having been sprayed with endosulfan at 500 and 1000 g a.i. / ha, respectively. The residue fell below the detectable limit 5

days after spraying at both doses. Dethle and kale (1991) analyzed residues of endosulfan by gas liquid chromatography in seeds of chickpea sprayed at twice than recommended dose and reported that the residues were at undetectable level. The residues of endosulfan resulting from three sprays in mustard seed at harvest by GLC was 0.065 and 0.145 mg/kg for the recommended and double dosages, respectively (Udean *et al.* 1991). Endosulfan could be used for the control of insect pests of pigeonpea without problem of excessive residue in the grains (Chawla and Jora, 1992). According to Senapathi *et al.* (1992) residues were concentrated in the husk than in the grain and also recommended that neither grains nor husk are consumed following application of quinalphos and monocrotophos, but the grains may be safely consumed after treatment with endosulfan.

Gopal and Mukharjee (1993) determined the residue of endosulfan on egg plant, mustard and chickpea and reported that alpha isomer was degraded more rapidly than the beta isomer, Beta isomer accumulated during the first 3 days following treatment. The total endosulfan residues in seeds from the treated mustard was 0.08 to 0.12 mg / Kg and were at or below the limits of detection (0.02 mg / Kg) in chickpea seeds following harvest. Ravi and Verma (1997)<sup>a</sup> recommended mixture of diflubenzuron with endosulfan for the control of *H.armigera* in chickpea and suggested safe interval before consumption for endosulfan on chickpea as 4 days. Naseema Beevi *et al.* (1997) reported that when endosulfan @ 0.07% and 0.14% during flowering and pod formation stage was applied in cowpea the residues were dissipated to below detectable level on 15<sup>th</sup> day in low dose while it was 0.3 mg / kg in higher dose. According to Tanwar and Honda (1998) the half lives of foliar application of endosulfan at 350 and 700 g



a l / ha during rainy season were 42 and 47, days respectively on foliage and 5–8 and 5 days, respectively on pods. Terminal residues at harvest on pigeonpea pods and pod covers were 1.73 and 2.45  $\mu\text{g}$  / gram at recommended and double concentrations, respectively, corresponding values for grain were 0.43 and 0.79  $\mu\text{g}$  / gram, respectively.

### Cost Benefit ratio

Parsai *et al.* (1989) tested eleven insecticides against *H. armigera* on chickpea and reported that the highest cost benefit ratio (1:5.1) was obtained with endosulfan. According to Datkhile *et al.* (1996) endosulfan 0.07% recorded 5.3 and NPV 250 LE / ha 2.6, Neemark 0.2% 2.7 and NSKE 1.2 cost benefit ratios in chickpea against gram pod borer. Patel *et al.* (1997) reported that endosulfan 0.035% gave the highest incremental cost benefit ratio (1:14.1), followed by endosulfan wp 0.035% (1:12.9) and chlorpyrifos 0.02% (1:12.1). NSKE suspension 3% gave 1:11.7 cost benefit ratio which was less effective and economical for controlling *H. armigera* in pigeonpea.

### Oviposition Deterrency Effect of Neem

Fagoonee (1981) reported that crude alcoholic extracts of dried neem leaf repelled *Crociodolomia binotalis* Zeller female from treated cabbage leaves at a distance of about 25 cm. In *H. armigera*, the volatiles of neem seed kernels and their aqueous distillates offered at a distance prevented contact and repelled the moths (Schmutterer, 1990). Saxena and Rembold (1983) found that azadirachtin alone neither repelled *H. armigera* adults nor deterred egg laying but due to presence of organosulphur compounds including dipropyl disulphide helped in repelling adults and deterred egg laying (Balandrin *et al.*, 1988). Oviposition deterrency effect of azadirachtin was reported by Schmutterer (1990).

According to Murugan *et al.* (1995) neem extract had both antifeedant and antiovipositional effects on the *Helicoverpa* moths. Jeyakumar and Gupta (1999) reported that neem seed kernel extract 10 and 7.5% treatments reduced oviposition to 60.9 and 59% compared to control

In the sheep blowfly, *Lucilia sericata* neem oil and the formulated NSKE AZT-VR-K were powerful ovipositional deterrent agents especially AZT-VR-K provided 100% repellence at 0.02% (Rice *et al.*, 1985). According to Neumann and Isman (1995) 1% crude neem oil emulsion significantly reduced the proportion of eggs laid by *S.litura* on treated cabbage plants

#### **Neem Effects on *H.armigera***

Neem azadirachtin besides being an antifeedant has been shown to interfere with growth, moulting and ecdysis (Rembold and Sieber 1981), reproduction (Dorn *et al.*, 1986) and mortality (Rembold *et al.*, 1981) of various insects. NSKE at higher concentrations reduced egg production and hatching percentage of many insects (Brattson, 1983). Neem has adverse effects on ovarian development and fecundity and fertility of adults (Karnavar, 1987), effective against nearly 200 insects and mite species (Saxena, 1989). Neem affected growth and feeding rates at 5-20 ppm in many laboratory experiments against a variety of insect species (Mordue and Blackwell, 1993).

Reduced fertility/fecundity in *H.armigera* due to NSKE was observed by Joshi and Sitaramiah (1979). Neem extracts have been observed to effect the morphology and development of chickpea pod borer *H.armigera* (Jabbar *et al.*, 1988). According to Tahir Anwar *et al.*, (1993) topical application of neem oil 0.001% on thoracic region of the *H.armigera* larvae

had no significant effect on the longevity of both the sexes. Murugesan and Jacob (1994) reported that with increase in NSKE on *Heliothis armigera* and *S.litura* food intake gets reduced, growth becomes slower and moulting is inhibited.

The  $EL_{95}$  Values for azadirachtin (doses for 95% ecdysis inhibitory activity) for first instar larvae of *H.zea* and *H.virescens* were 2ppm, for *S.frugiperda* 1ppm and for *Pectinophora gossypiella* Saund 10ppm (Kubo and Klocke, 1982).

According to EL-Sayeed (1985) 0.2-0.5% suspension of ground neem seeds caused 100% mortality of *S.littoralis* by the end of the larval period, and also caused pupal mortality and adult deformity. Antifeedant and growth inhibitory effects of neem limnoids in *S.litura* were reported by Murugan and Jeyabalan, (1995); Koul *et al.* (1996). Application of azadirachta extract affected behaviour and vitality of larvae and adults of *S.frugiperda* (Breuer and Schmidt, 1996).

### **Neem Antifeedant Effects**

Pradan *et al.* (1962) were among the first to report that extracts from seeds of neem *Azadirachta indica* A.Juss. were antifeedant to the desert locust *Schistocerca gregaria* Forskal.

According to Schoonhoven *et al.* (1987) contact with azadirachtin makes disruption in food intake and increases the locomotory activity of insects. Neem extracts had both antifeedant and antiovipositional effects on the *Helicoverpa* moths (Murugan *et al.*, 1995). In studies on the feeding behaviour of larvae of lepidopterous insects such as *S.littoralis*, *S.frugiperda*, *S.exempta*, *H.virescens*, *H.zea*, *H.armigera*, *Trichoplusia ni* (Hb.) and *M.brassicae* azadirachtin reduced feeding (Schmutterer, 1990).

Neem oil possesses distinct antifeedant activity against cotton bud worm *S.littoralis* (Koul, 1987). Chen *et.al.* (1996) reported that neem seed kernel extract at concentrations ranging from 0.2-4.0% reduced the number of eggs from 87.5 to 99.2% compared with eggs in untreated guava fruit in choice test by the oriental fruit fly *Bactrocera dorsalis*. Prabal Saikia and Rameswaran (2000) conducted free choice method to test the repellent action of plant derivatives against *Cnaphalocrosis medinalis* (Guen) and reported that neem oil 60 EC 1% when used 38.3% larvae moved towards neem treated and 61.6% towards control leaves after settlement observed.

#### **Use of Robin blue in HaNPV**

Efficacy of entomopathogens can be maximized by conserving their stability in the environment (Ignoffo and Falcon, 1978). Major obstacle in the use of insect viruses in field situations is the rapid inactivation by ultraviolet radiation (Gudauskas and Canerday, 1968; Jaques, 1985; Ignoffo and Garcia, 1992).

Rabindra and Jayaraj (1988) reported that when HNPV was applied to *C.arietinum* plant at 1,00,000 polyhedral bodies / ml and exposed to field conditions, its persistence was increased with 1% Robin blue and Tinopal. According to Rabindra *et al.* (1989) addition of whole milk (20%), whole egg homogenate (10%), Ranipal (0.5%), Robin blue (0.5%) and cotton seed oil (5%) to ULV sprays of HNPV in chickpea effectively controlled the noctuid *H.armigera* and reduced pod damage and significantly increased yields.

#### **Effect of HaNPV on Different Age Groups of *H.armigera***

Phenomenon of maturation immunity where the larvae can not be infected by a pathogen beyond a particular age has been reported in

*H. armigera* (Whitlock, 1977). Ignoffo (1966) reported that as the age of the *H. zea* and *H. virescens* larvae increases their susceptibility to the NPV decreases. The same was also reported by Allen and Ignoffo (1969) in case of *H. zea*. According to Boucias *et al.* (1980) as the age of velvet caterpillar, *Anticarsia gemmatalis* (Hubner) larvae increases the time taken for NPV infected larvae to die increases. Evans (1981) showed that 90 per cent of the variability of *Memestra brassicae* (Linnaeus) to NPV susceptibility could be accounted for the increase in body weight. Smits and Vlak (1988) reported that the time for NPV infected *Spodoptera exigue* (Hubner) larvae to die increases with age of the larvae.

Prasad and Ramakrishnan (1993) found that *S. litura* larvae after certain age could not be infected by nuclear polyhedrosis virus (NPV). Jayachandran and Chaudhari (1996) reported that in case of *S. litura* the mortality due to NPV infection increases due to increased dosage and decreases with host age. According to Ingahalli *et al.* (1995) during NPV infection in the armyworm *Mythimna separata* (Walk.) the fat body, gut and integument indicated hypoglycemia, whereas the haemolymph demonstrated the hypertrehalosemia and hyperglycemia. These changes were similar to the ones observed during starvation, but hypertrehalosemia was more evident than hyperglycemia during starvation. The growth rate, gross and net efficiency of food utilization for body matter were observed to be decreased during the course of NPV infection to *H. armigera* (Kencharaddi and Jayaramaiah, 1997). It was also reported that LC<sub>50</sub> of HaNPV is  $2.9 \times 10^4$ ,  $5.33 \times 10^4$  and  $2.7 \times 10^5$  PIBS / ml for first, third and fifth instars of *H. armigera*, and the LT<sub>50</sub> is 4.8 days at  $2.0 \times 10^5$  PIB / ml for 1<sup>st</sup> and 3<sup>rd</sup> instars, respectively. Chaudhary (1997) calculated LC<sub>50</sub> value for 4 and 12 day old larvae of *Spilosoma obliqua* Wik. as  $2.6 \times 10^4$ ,  $2.96 \times 10^5$  PIB / ml, respectively and suggested that virus application at early stages of the

larvae will be more effective for maximum foliar protection with early death of the larvae. Increasing virus dosage slightly increased speed of kill in respect of HzSNPV against *H. zea* and for AfMNPV against *S. frugiperda* (Farrar and Ridway, 1999).

Patil *et al.* (1989) studied the sublethal effects of the LC25 and LC50 NPV treatments on *M. seprata* parent, F<sub>1</sub> generations and the results revealed that in both the generations weight of the larval, pupal and adult stages and the adult longevity decreased, while developmental duration for the larval and pupal stages increased significantly. Further, pupation and adult emergence rates, growth index, fecundity, average egg production, per cent egg hatchability declined considerably. The above results were also demonstrated in spruce bud worm (Morris, 1977) and in the cotton boll worm *H. zea* (Luttrell *et al.*, 1982).

## MATERIALS AND METHODS

Studies on the "Effect of different IPM components on *Helicoverpa armigera* Hubner and their impact on natural enemies in Chickpea " were conducted at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, during two chickpea seasons (post rainy season 1998-99 (November to February) and 1999-2000 (September to February). The materials used and methods employed in conducting these experiments are elucidated in this chapter.

### 3.1 FIELD EXPERIMENTS

The influence of IPM components on *H.armigera* and their impact on natural enemies in chickpea was investigated by conducting field experiments in ICRISAT farm, Patancheru during post rainy season (*rabi*) 1998-99 and 1999-2000.

#### 3.1.1 Experimental Design

The research was conducted in black percision (BP) 7A field of ICRISAT farm with an area of 8000 Sq. m during *rabi* 1998-99, and BP14 field of ICRISAT farm with an area of 9000 Sq. m during *rabi* 1999-2000. The area was divided into 24 plots, each plot measuring 288 Sq. m (18 x16 m during *rabi* 1998-99 and 24 x 12 m during *rabi* 1999-2000), to conduct the experiment with six treatments in four replications each. Randomized block design was used to conduct the trial (Plate.1).

#### 3.1.2 Sowing

A high yielding, desi, medium duration variety ICCV 37 (kranti) seed was obtained from ICRISAT. To reduce the incidence of seed borne diseases such as collar rot, and root rot the seeds were treated with Mancozeb @ 2 g / Kg of seed. The treated seeds were sown on 11th November during *rabi* 1998-1999 and 22nd October during *rabi*



Plate 1 : Field view of the experimental plot



Plate 2 : Bird perch in the experimental plot.



1999-2000 with the spacing of 60 cm between rows and 15 cm within a row

### 3.1.3 Efficacy of Different Treatments Against Gram pod Borer and Their Natural Enemies

A field experiment was conducted in a randomized block design with six treatments and four replications. The experiment was conducted in 288 Sq m area plots with ICCV 37 chickpea variety. The following treatments were used to study the effect of treatments on gram pod borer and their natural enemies.

- T<sub>1</sub> Neem (AZA 3%) 0.006% during *rabi* 1998-99 and (Nivaar 1500 ppm) @ 1750 ml / ha during *rabi* 1999-2000.
- T<sub>2</sub> *Heliothis* Nuclear Polyhedrosis Virus 250 LE / ha
- T<sub>3</sub> Fixing bird perches @ 1 perch / plot.
- T<sub>4</sub> Endosulfan 35 EC 0.07%.
- T<sub>5</sub> Integrated Pest Management (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>)
- T<sub>6</sub> Control

#### 3.1.3.1 Neem

During *rabi* 1998-99 30,000 ppm neem product AZA3% was supplied by Dr. Baliga, Technical Consultant, Mumbai. This AZA 3% was obtained through ICRISAT and used in this experiment. 20 ml of AZA 3% in 10 liters of water was mixed to obtain 60 ppm or 0.006% used for spraying. During *rabi* 1999-2000 neem product Nivaar (1500 ppm) was obtained from ICRISAT sprayed at recommended rate i.e., 1750 ml / ha (50 ml / 10 l of water). This spray fluid requirement was standardized before spraying by using water at 10 liters per plot.

### 3.1.3.2 *Heliothis armigera* nuclear polyhedrosis virus (HaNPV)

*Heliothis armigera* Nuclear Polyhedrosis virus was produced at ICRISAT-NPV laboratory and used for the studies. The HaNPV stock solution was prepared such that 1 ml of HaNPV solution equals to one larval equivalent (LE) containing  $6 \times 10^9$  POBs. Since, virions were sensitive to ultra violet rays of sunlight, the spraying was done in evening hours. In order to protect the polyhedron particles from ultra violet rays robin blue was mixed in the spray solution @ 1 ml/l of spray fluid. HaNPV was used @ 250 LE / ha.

### 3.1.3.3 Bird perches

Dried up tree branches were cut to create a natural tree like appearance in the field, to be used as a perch by the visiting bird (Plate.2). The vertical height of the perch was about 1.5 m from ground, a suitable height for insectivorous birds to rest and search for the larvae in the chickpea canopy. The perches were installed and maintained @ one perch per plot from 21 DAS and 32 DAS during 1998-99 and 1999-2000, respectively, till crop harvest.

### 3.1.3.4 Endosulfan

Endosulfan 35 EC was obtained from ICRISAT and used in the experiment. To prepare 0.07% concentration, 2 ml of the stock solution was mixed in a liter of water.

The treatments were given five times during *rabi* 1998 – 99 and 1999 – 2000 at 15 days interval during cropping period. The sprays were initiated after pest population was above ETL (2 small size larvae/ plant). The sprays were imposed on 21,37, 52, 67 and 84 DAS during *rabi* 1998 – 99 and 32, 47, 62, 78 and 94 DAS during *rabi* 1999 – 2000. The variation of dates of spraying during the two years of study was due to the variations in incidence, stage of the crop and condition of the field.

$T_2$  (HaNPV) treatment at all the above mentioned days and in IPM ( $T_6$ ) at 37 and 84 DAS during *rabi* 1998-99 and 47 and 94 DAS during *rabi* 1999-2000 received HaNPV spray @ 250 LE / ha after 4 p.m. mixed with UV protectant

In all the replications of  $T_3$ , bird perches were installed @ one perch per plot on the day when first spray of other treatments was given and retained in the plot till last observation was taken.

In  $T_5$  (Integrated Pest Management) plot, bird perches were installed @ one perch per plot on the day of first spraying and kept until the last observation was taken. At the same day  $T_5$  received neem spray. Second and third were HaNPV 250 LE / ha and endosulfan 0.07%, respectively. Once again neem and HaNPV were given as fourth and fifth spray, respectively, to manage *H.armigera* throughout the crop period, in  $T_5$ .

### 3.1.3.5 Methods of observation

From each plot twenty plants were randomly selected for recording observations. In each plant the number of eggs, small size (first & second instars), medium size (third & fourth instars) and large size (fifth & sixth instars) larvae were counted at weekly interval. The observations were taken 15 DAS onwards during *rabi* 1998-99 and 24 DAS during *rabi* 1999-2000 with weekly interval till crop maturity. The mean number of larvae/eggs per plant at different crop stages in different treatments were worked out.

The data were subjected to square root transformation for analysis in randomized block design.

### 3 1 4 Effect of Different Treatments on Natural Enemies

#### 3 1 4 1 Monitoring the activity of soil inhabiting natural enemies in different treatments.

For monitoring soil inhabiting natural enemies pitfall traps were used (Plate 3). One litre plastic containers were used as pitfall traps. These containers were placed in the soil by burrying to the ground level at the rate of three traps per plot. These traps were installed at 21 DAS during *rabi* 98 – 99 and 30 DAS during *rabi* 1999 – 2000 at random in the plot. These jars acted as traps to monitor soil dwelling natural enemies.

One ml of formaldehyde and 1 ml of soap water were mixed with one litre of water and poured into the trap up to 3/4 the volume, so that natural enemies falling into the trap will be killed immediately after falling and preserved well in the trap without spoilage upto observation.

#### Methods of observations

Observations were taken once in 10 days till crop maturity. Individual traps were removed from the soil and then formaldehyde, soap water mixtures along with collected insects were poured into a filter to separate the insects from the collected fluid. From the collection, individual insects were separated using camel hair brush/forceps and were identified. Thus, observations were made in all the treatments across the trial. The traps were cleaned with water and replaced once again in pits at ground level with formaldehyde & soap water solution.

The total number of natural enemies in all traps of a treatment was worked out. The mean number of natural enemies present during different crop stages in different treatments were calculated. The data collected were analyzed in randomised block design after transforming into square root

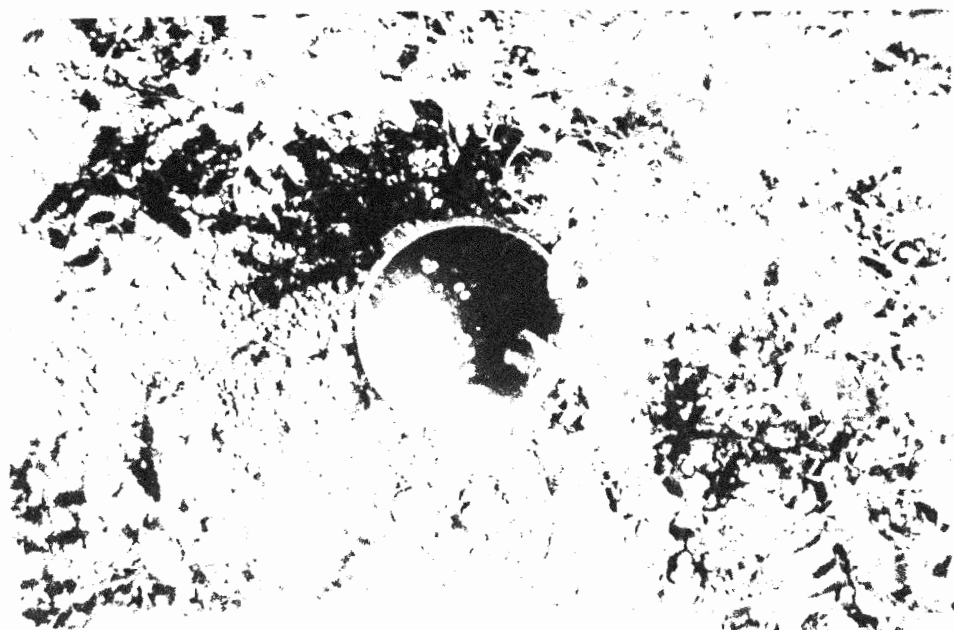


Fig. 4. Pitfall trap for collecting soil inhabiting natural enemies.



Fig. 5. The Zai-fu collecting aerial natural enemies.

values to get the effect of different treatments on the activity of soil inhabiting natural enemies.

#### 3.1.4.2 Effect of different treatments on the aerial natural enemies

De Vac (Plate 4) was used to assess the activity of various predators and parasitoids in different treatments, which were inhabiting on the crop canopy (aerial natural enemies). Due to the vacuum created inside the trap, the insects found in the crop canopy were captured inside the trap. This trap was operated twice during *rabi* 1998 – 99 i.e. at 22 DAS and 54 DAS. During *rabi* 1999 – 2000 this trap was not operated due to machine failure. But it was substituted with hand operated trap, however due to stickiness of foliage because of presence of malic and oxalic acids most of the aerial natural enemies were stuck to the foliage.

At the time of De Vac operation, operator walked twice on any of the two rows in a plot for one minute by carrying De Vac on his back and holding mouth of the trap near the crop canopy. The collected material was transferred into a polythene cover and labelled. The counting and identification was carried out in the laboratory.

Total number of natural enemies in different treatments were calculated and subjected to randomized block design analysis to assess the effect of different treatments on the natural enemies in the crop canopy.

#### 3.1.4.3 Efficacy of different treatments on egg, larval and pupal parasitoids

To evaluate the percentage egg parasitism, 100 eggs along with leaves @ one egg per leaf per vial for different treatments were collected and observed daily till larvae or parasitoid hatched out.

For observing larval or larval-pupal parasitism 100 larvae per treatment were collected, and released in individual glass vials and observed daily for parasitism. Larvae were fed with soaked chickpea seeds and the feed was changed at alternate days. Observations were made upto adult emergence.

Two such collections were made on 25 DAS and 57 DAS during *rabi* 1998-99 and 36 and 73 DAS during *rabi* 1999-2000.

Total number of parasitised eggs and larvae and pupae were counted separately and the percentage parasitisation was worked out. The data were subjected to randomized block design analysis after transforming the percentage values into arc sin values.

### 3.1.5 Pod Damage

Net plot area (14 x 6m) was marked and plant population in net plot area was counted before harvesting.

From net plot area 20 plants were removed randomly and all the pods were removed and collected in a cover and labelled. In the laboratory, number of healthy and pod borer damaged pods were counted and percentage pod damage was worked out for all the plots using the formula given below.

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

### 3.1.6 Yield

Net plot area was separately harvested and threshed 3 days after harvesting. Threshed grains were cleaned and weighed. The pods collected from 20 plants were removed from net plot for working out per cent

pod damage and also threshed, cleaned and weighed and was added to the net plot yield

The data were subjected to RBD analysis to know the effect of different treatments on yield.

### **3.1.7 Residue Analysis**

Pesticide residues present in husk and seed of chickpea in endosulfan treatment and IPM treatment plots were analyzed for residues of endosulfan

#### **3.1.7.1 Method of sample collection**

To determine the residues of endosulfan in chickpea plots treated with endosulfan and endosulfan received IPM treatment, ten chickpea plants were collected at random in all the four replications at the time of harvest, air dried and preserved in the refrigerator.

#### **3.1.7.2 Extraction and clean up**

The chopped and blended chickpea husk, seed, 200g and 100g, respectively was taken from the composite sample and extracted with 300ml mixture of n-hexane:isopropanol (2:1). The filtered extract was washed with distilled water and the aqueous phase was discarded. The hexane layer was collected through anhydrous sodium sulphate. A drop of keeper was added and extract was concentrated.

The concentrated extract was dissolved in 45-50 ml of hexane:acetone (9:1) and little quantity of Darco G 60 (activated charcoal) was added with occasional shakings. This was filtered through filter paper and residues were washed with 3X15 ml of hexane:acetone (9:1) mixture making it ready for GC analysis.



### 3 1 7 3 Determination

The residue estimation was done using GCECD with the following parameters

GC	:	Packard 437A
Detector	:	Electron Capture Detector
Column	:	4%SE 30+6% OV 210
Column (Oven)	:	190
Temperature(°C)		
Detector temperature(°C)	:	250
Injector temperature(°C)	:	270
Carrier gas flow (ml/min)	:	N <sub>2</sub> 60
Retention time (min)		
Endosulfan I	:	7.3
Endosulfan II	:	10.5
Endosulfan sulphate	:	2.8

### 3 1 7 4 Recovery

Chickpea plants were collected from control plots and after chopping and blending, were transferred to the reagent bottles at the rate of 100 g. A known amount of standard solution (equals to 1ppm) was added. After shaking the contents, the samples were subjected to clean up for the determination of residue. The recovery obtained was 99 per cent for endosulfan I&II and 97.5 per cent for endosulfan sulphate.

## 3.2 LABORATORY STUDIES

### 3.2.1 Effect of Neem on *H. armigera* Oviposition

Sixty, 30 days old potted chickpea plants were used for this study. Two pots in each treatment and fifteen replications were maintained in a cage. Neem @ 0.006% was sprayed with hand operated sprayer as one treatment and water spray as another treatment. Fifteen pairs of *H. armigera* adults less than 12 hrs old were released into the cage immediately after spraying. 10% honey solution on cotton swabs was provided in this cage as adult food. The number of eggs per pot were counted and recorded in treated and untreated pots daily until the death of adults. Total number of eggs per pot was calculated.

The data were tested by using two sample t-test to know the significance of the treatments.

### 3.2.2 Larval Preference for Neem

#### Choice test

In large petriplates (15 cm diameter) neem (azadirachtin) sprayed chickpea leaves on one side and water sprayed chickpea leaves on opposite side were kept. Ten first instar larvae were released in the middle. Their movement towards neem treated or control chickpea leaves were observed at hourly interval until they have settled for continuous feeding. Ten replications were maintained and the same process was repeated for third instar larvae also. But for fifth instar larvae, due to cannibalism, in each petri plate one larva was released in middle and a total of ten petri plates constituted one replication, and for 10 replications 100 petri plates were maintained and their preference was observed.

### **No choice test**

In large petri plates neem (azadirachtin) sprayed chickpea leaves were kept and ten first instar larvae were released on them. Larval searching behaviour was observed at hourly interval until they have settled for continuous feeding. Ten replications were maintained. The same process was repeated for third instar larvae. But for fifth instar in each petri plate one larva was released, a total of ten petri plates constituted one replication. Hundred petri plates were maintained for ten replications. Larval preference was recorded and expressed as per cent settled on neem and tried for another food source.

Two sample t-test was used to know the significance of preference between neem and water sprayed chickpea leaves for different instars.

### **3.2.3 Effect of Neem on the Different Age Group of *H. armigera***

Neem 0.006% was sprayed on field collected chickpea leaves and pods. Then air dried for ½ hour. Then the leaves and pods were fed to three age groups viz. first & second, third & fourth, fifth & sixth instars. For each age group ten replications with 12 larvae in each replication were maintained. For each age group control was also maintained separately. Larval mortality was recorded from 24 hrs after treatment upto pupation. Larval duration, pupal period and pupal weight were recorded. Adult mortality was also observed.

Pupae were collected from larvae that received neem treatment. Adults emerged from these pupae were tested for their fecundity. The fecundity was observed by releasing adults of *H.armigera* female:male in 1:2 ratio in oviposition chambers which were provided with egg laying tissue papers and 10% honey in cotton swabs. The number of eggs

was recorded daily from third day after release upto their death. Oviposition period was also recorded. Total number of eggs per female was calculated.

The egg hatching was observed by keeping a small piece of egg laying tissue paper along with the eggs in closed plastic boxes. The number of eggs hatched were recorded and hatching per cent was calculated.

The data were tested by using two sample t-test.

### 3.2.4 Persistence of HaNPV

Persistence of HaNPV under field conditions is one of the main drawbacks in the use as a bio-insecticide. Of the several locally used UV protectants Robin blue is the most popular one. Hence its efficiency was tested to increase HaNPV persistence under field conditions. The treatments were

- T<sub>1</sub> HaNPV @ 6 x 10<sup>9</sup> POB / l alone.
- T<sub>2</sub> HaNPV @ 6 x 10<sup>9</sup> POB / l +1% Robin blue
- T<sub>3</sub> Control (water spray)

The treatments were applied on chickpea crop in three different 100 m apart patches. From each treatment leaves and pods were collected immediately after treatment, 1, 2, 3, 4, 5, 6 and 7th day after treatment. Eighty four laboratory reared third instar larvae / treatment (12 larvae / replication) were used. Seven replications were maintained. Larvae were starved for one day before treatment. Mortality of larvae was recorded every day until pupation and mortality per cent was calculated. This experiment was repeated for 3 times.

The data were subjected to arc sin transformation and analyzed by Randomized Block Design.

### 3.2.5 Effect of HaNPV on three different age groups of *H. armigera*

Field collected chickpea leaves and pods were sprayed with HaNPV @  $6 \times 10^9$  POB / l., air dried for  $\frac{1}{2}$  hr., and then HaNPV treated leaves and pods were fed to three age groups. After 24 hrs the feed was changed with fresh untreated soaked chickpea seeds. Mortality of the larvae was recorded from 24 hrs after treatment up to pupation. Pupal abnormality and adult emergence were also recorded.

### 3.2.6 Effect of HaNPV Treatment During Larval Stage on Fecundity and Egg Hatching of *H.armigera*.

Pupae were collected from the population that received HaNPV treatment during larval stage. For this experiment four treatments were used (1) female from HaNPV treated population and male from normal population, (2) male from HaNPV treated population and female from normal population, (3) both male and female from HaNPV treated population and lastly (4) male and female from normal population. The moths were released in the egg laying chambers made of plastic which were provided with egg laying tissue papers and 10% honey solution on cotton swabs. The egg laying was recorded from third day after release until the death of adults. Five replications were maintained, and the experiment was repeated three times. The data were subjected to square root transformation for analysis.

From the same treatments a small piece of egg laying tissue paper containing more or less hundred eggs was kept for egg hatching. The number of eggs hatched was recorded and per cent hatch was calculated. The per cent of eggs hatched were subjected to arc sin transformation for analysis.

The observations were analyzed by using Completely Randomized Block Design.

## RESULTS

### 4.1 FIELD STUDIES

#### 4.1.1 Population Fluctuations of *H.armigera* during *rabi* 1998-99

The moth activity of *H.armigera* was seen throughout the crop period with peaks at 43 DAS (100.7 moths/trap), 71DAS (55 moths/trap) and 92 DAS (58.3 moths/trap).

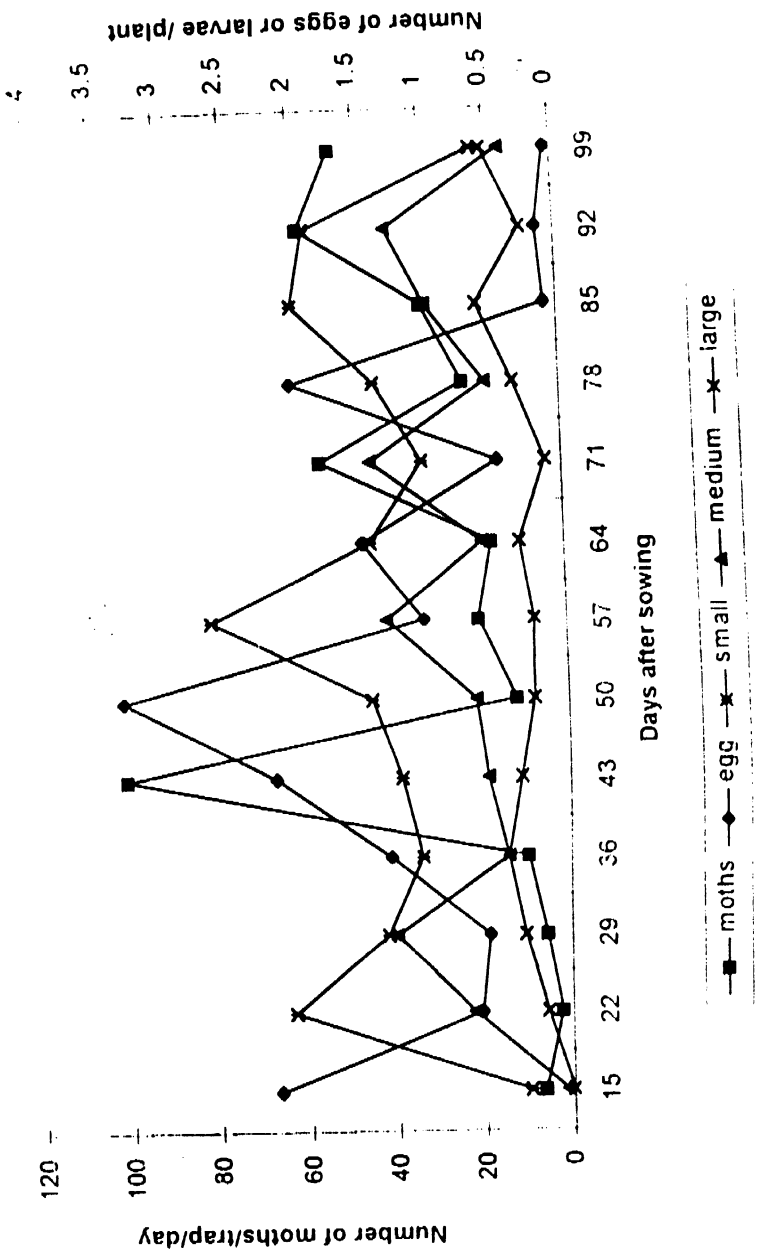
Observations on the number of eggs during 1998-99 season showed an average of 1.22 eggs per plant at vegetative stage and 2.00 eggs/ plant at flowering stage with a peak of 3.36 eggs/plant at 50 DAS (Appendix I). There was little difference in mean number of eggs/plant during podding and preharvest stages, indicating a similar moth activity throughout that period.

Data on small size larval counts indicated 1.5, 1.9, 1.5 and 1.3 larvae per plant during vegetative, flowering, pod formation and preharvest stages of the crop, respectively. This clearly showed uniform occurrence of small larvae throughout the crop period which was the result of continuous adult activity.

Maximum number of medium size larvae were observed at pod formation stage (1.45 larvae/plant at 71DAS) (Appendix III). The medium size larval population in the other stages of the crop was around 0.8 larva/plant.

Large size larval peak was noticed at preharvest stage with 0.39 larva per plant, and the population during the other stages was around 0.3 larva per plant.

Fig. 1 : Population fluctuations of *H.armigera* in chickpea during rabi 1998-99



The pooled larval data showed the peak activity with 3.0 larvae per plant during the flowering stage of the crop, later the population declined slightly and reached 2.3 larvae/plant by preharvest stage of the crop

#### **4.1.2 Efficacy of the Treatments on Ovipositional Behaviour of *H.armigera* during rabi 1998-99**

In order to assess the efficacy of different treatments on the ovipositional behaviour of *H. armigera*, studies were conducted in chickpea crop during rabi 1998 – 99. The results are presented in Table 1. The number of eggs per plant were recorded at weekly interval in different treatments on 20 random plants and the mean number of eggs per plant during different stages of crop are presented. The crop received a total of five sprays during the entire cropping period, two sprays (21 DAS, 37 DAS) during vegetative stage, one spray during flowering stage (52 DAS) and two sprays during pod formation stage (67 DAS, 84 DAS).

##### **Vegetative stage**

The plots treated with neem and IPM treatment which received neem as first and HaNPV as second spray were found highly effective in reducing egg laying by *H.armigera* with lower number of eggs per plant (0.65 and 0.69 egg/plant, respectively) during vegetative stage. The remaining treatments, HaNPV (0.82), endosulfan (0.84) and bird perches (0.94) were on par with significantly less number of eggs per plant than control (1.22).

##### **Flowering stage**

During flowering stage also neem (1.33 eggs/plant), HaNPV (1.37 eggs/plant) and IPM (1.40 eggs / plant) which received endosulfan as third spray were on par and found superior in keeping the egg number at low level. But and were as effective as neem with and, respectively. Control (1.99) recorded more number of eggs. Bird



**Table 1: Effect of the treatments on oviposition behaviour of *H. armigera* during *rabi* 1998-99.**

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of eggs per plant)			
Neem 0.006% (AZA 3%)	0.65 (0.8060) <sup>a</sup>	1.33 (1.1526) <sup>a</sup>	0.58 (0.7635) <sup>a</sup>	0 (0.2236) <sup>a</sup>
HaNPV250LE/ha	0.82 (0.9063) <sup>ab</sup>	1.37 (1.1688) <sup>a</sup>	0.73 (0.8561) <sup>bc</sup>	0.07 (0.3446) <sup>bc</sup>
Bird perches one/plot	0.94 (0.9681) <sup>b</sup>	1.69 (1.3005) <sup>bc</sup>	0.73 (0.8537) <sup>bc</sup>	0.06 (0.3354) <sup>bc</sup>
Endosulfan 0.07%	0.84 (0.9183) <sup>ab</sup>	1.74 (1.3195) <sup>c</sup>	0.68 (0.8239) <sup>ab</sup>	0.02 (0.2622) <sup>ab</sup>
IPM	0.69 (0.8326) <sup>a</sup>	1.40 (1.1812) <sup>ab</sup>	0.58 (0.7579) <sup>a</sup>	0.01 (0.2500) <sup>ab</sup>
Control	1.22 (1.1038) <sup>c</sup>	1.99 (1.4090) <sup>c</sup>	0.87 (0.9328) <sup>c</sup>	0.09 (0.3791) <sup>c</sup>
S.Ed.	0.064	0.057	0.043	0.052
CD	0.135	0.120	0.090	0.111

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

perches (1.69) and endosulfan (1.74) showed no effect on *H. armigera* ovipositional behavior and were on par with control

### **Pod formation stage**

It is one of the most critical stages of the crop, where the infestation had direct effect on yield. IPM (0.58) which received neem as fourth and HaNPV as fifth spray and neem (0.58) showed good effect in minimizing the oviposition of *H. armigera*. Endosulfan (0.68) treatment was also found as effective as IPM and neem treatments. Control plot had the highest number of eggs throughout the pod formation stage with 0.87 egg per plant. HaNPV (0.73) and bird perch (0.73) treatments showed little effect on repelling the ovipositing adults, being on par with control.

### **Preharvest stage**

During this period neem treatment (0) provided maximum repellency for *H. armigera* oviposition. IPM (0.01) and endosulfan (0.02) treatments also recorded less number of eggs and were on par with neem. Bird perches (0.06) and HaNPV (0.07) were on par with control treatment (0.09)

#### **4.1.3 Efficacy of the Treatments on Small Size (first & second instars)**

##### **Larvae of *H. armigera* during rabi 1998-99**

Studies were conducted to assess the efficacy of different IPM components in managing the small size larval population. Observations were recorded at weekly interval on 20 random plants per plot and the mean number of larvae per plant at different crop stages are described below (Table 2).

### **Vegetative stage**

During this stage of the crop two sprays were given with the respective treatments, once at 21 DAS and another at 37 DAS. The plots sprayed with endosulfan recorded the lowest number of larvae per plant (0.91) but it was on par with HaNPV (1.09). IPM which received neem as first and HaNPV as second spray and neem and bird perches (1.12, 1.18 and 1.25 larvae/plant respectively) were statistically on par and significantly superior to control (1.47) in bringing down the larval population of *H.armigera* during vegetative stage of the crop.

### **Flowering stage**

The sprays in the respective treatments were given at 52DAS coincided with flowering stage of the crop. The plots with IPM treatment which received endosulfan as third spray recorded the lowest number of larvae per plant (1.29). However the plots treated with endosulfan (1.34) and HaNPV (1.38) were also on par with IPM. Neem (1.43) recorded next in the order of efficacy. The control plot recorded the highest number of larvae (1.88). Bird perches showed no effect on managing small larvae and it was on par with control.

### **Pod formation stage**

During podding stage the crop received two sprayings at 67 DAS and 84 DAS. The IPM treatment which received neem as fourth spray and HaNPV as fifth spray registered the lowest number of larvae (1.16). The plots sprayed with HaNPV (1.23), neem (1.28) and endosulfan (1.28) were also on par with IPM and recorded less number of larvae compared to control. Control recorded the highest number of larvae (1.49). Bird perches plot showed no effect in managing small size larvae by recording 1.33 larvae/plant and was on par with control.

Table 2 : Efficacy of the treatments in managing small size larvae of *H.armigera* during *rabi* 1998-99

Treatment/ crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of larvae per plant)			
Neem 0.006% (AZA 3%)	1.18 (1.0852) <sup>b</sup>	1.43 (1.1971) <sup>b</sup>	1.28 (1.1308) <sup>ab</sup>	0.97 (0.9840) <sup>b</sup>
HaNPV250LE/ha	1.09 (1.0422) <sup>nb</sup>	1.38 (1.1741) <sup>nb</sup>	1.23 (1.1084) <sup>nb</sup>	0.95 (0.9745) <sup>b</sup>
Bird perches one/plot	1.25 (1.1165) <sup>b</sup>	1.84 (1.3554) <sup>c</sup>	1.33 (1.1528) <sup>bc</sup>	1.00 (1.0003) <sup>bc</sup>
Endosulfan 0.07%	0.91 (0.9517) <sup>a</sup>	1.34 (1.1563) <sup>a</sup>	1.28 (1.1326) <sup>ab</sup>	0.94 (0.9680) <sup>b</sup>
IPM	1.12 (1.0560) <sup>b</sup>	1.29 (1.1361) <sup>a</sup>	1.16 (1.0778) <sup>a</sup>	0.27 (0.5180) <sup>a</sup>
Control	1.47 (1.2118) <sup>c</sup>	1.88 (1.3692) <sup>c</sup>	1.49 (1.2212) <sup>c</sup>	1.25 (1.1179) <sup>c</sup>
S.Ed.	0.045	0.019	0.033	0.056
CD	0.095	0.040	0.069	0.118

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

### **Preharvest stage**

The crop received fifth spray at 84 DAS during pod formation but its effect was measured at preharvest stage. Based on the results, IPM plot was the most efficient by recording the lowest population with 0.27 larva per plant and significantly superior to the rest of the treatments. Endosulfan (0.94) stood next in the order of efficacy but was on par with HaNPV (0.95), neem (0.97) and bird perches (1.00). Control registered the highest number of larvae (1.25) but was at par with bird perches.

#### **4.1.4 Efficacy of the Treatments on Medium size (third & fourth instars)**

##### **Larvae of *H.armigera* during rabi 1998-99**

To evaluate the effect of different IPM components in managing the medium (III & IV instars) size larval population, an experiment was conducted with a total of five sprays during the crop period, two sprays during vegetative, one spray during flowering, and two sprays during pod formation stage. The number of larvae per plant in different treatments were recorded at weekly interval and the mean number of larvae per plant at each crop stage are presented in Table 3.

### **Vegetative stage**

Neem (0.48 larva/plant) and HaNPV (0.49 larva/plant) on par and were found to be the most effective and significantly superior to the rest of the treatments by recording the lowest number of medium size larvae. Endosulfan (0.56), IPM which received neem as first spray and HaNPV as second spray (0.56) and bird perches (0.62) were on par and significantly superior to control (0.79) in bringing down *H.armigera* medium size larval population during vegetative stage of the crop.

### **Flowering stage**

During flowering stage IPM was the most effective treatment which received endosulfan as third spray with 0.58 larva per plant. HaNPV (0.62), neem (0.62) and endosulfan (0.64) were also as effective as IPM treatment in managing the medium size larvae at flowering stage. Bird perch plot also gave a significant reduction in the number of larvae per plant (0.72) compared to control (0.89).

### **Pod formation stage**

IPM that received neem as fourth and HaNPV as fifth spray was significantly superior to the rest of the treatments in managing medium size larvae with 0.68 larva per plant. Birds were active in plots with bird perches during this stage and recorded 0.81 larva per plant and stood next in second position. But HaNPV (0.83) and endosulfan (0.89) were on par with bird perches. Neem was the least effective with 0.90 larva per plant among the treatments while control plot recorded significantly high larval population (1.00 larva per plant).

### **Preharvest stage**

At preharvest stage also IPM showed its significant effect in managing the medium size larvae compared to other treatments by recording the lowest number of larvae (0.49). There was no significant difference in the number of larvae in the plots treated with HaNPV, bird perches and endosulfan (0.58, 0.61, 0.61, respectively). Once again neem was the least effective with 0.68 larva per plant among the treatments. Control plot experienced significantly higher larval population (0.84 larva per plant).

Table 3 : Efficacy of the treatments in managing medium size larvae of *H.armigera* during *rabi* 1998-99

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of larvae per plant)			
Neem 0.006% (AZA 3%)	0.48 (0.6890) <sup>a</sup>	0.62 (0.7878) <sup>a</sup>	0.90 (0.9483) <sup>c</sup>	0.68 (0.8215) <sup>c</sup>
HaNPV25:0LE/ha	0.49 (0.7026) <sup>a</sup>	0.62 (0.7850) <sup>a</sup>	0.83 (0.9126) <sup>bc</sup>	0.58 (0.7622) <sup>b</sup>
Bird perches one/plot	0.62 (0.7865) <sup>b</sup>	0.72 (0.8464) <sup>b</sup>	0.81 (0.9012) <sup>b</sup>	0.61 (0.7785) <sup>bc</sup>
Endosulfan 0.07%	0.56 (0.7498) <sup>b</sup>	0.64 (0.7982) <sup>ab</sup>	0.89 (0.9417) <sup>bc</sup>	0.61 (0.7824) <sup>bc</sup>
IPM	0.56 (0.7497) <sup>b</sup>	0.58 (0.7606) <sup>a</sup>	0.68 (0.8214) <sup>a</sup>	0.49 (0.7023) <sup>a</sup>
Control	0.79 (0.8890) <sup>c</sup>	0.89 (0.9419) <sup>c</sup>	1.00 (1.0003) <sup>d</sup>	0.84 (0.9184) <sup>d</sup>
S.Ed.	0.018	0.024	0.022	0.025
CD	0.039	0.051	0.046	0.053

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

#### 4.1.5 Effect of the Treatments on Large Size (fifth & sixth instars) Larvae of *H.armigera* during *rabi* 1998-99

The efficacy of different IPM components individually and in combination in managing large size larvae of *H. armigera* was tested and the results are presented in Table 4. Five sprays were given during the crop period, two at vegetative, one at flowering and the remaining two at pod formation stage.

##### **Vegetative stage**

Endosulfan stood first in controlling large size larvae by recording the lowest number (0.17) per plant during vegetative stage. IPM that received neem as first and HaNPV as second spray in addition to bird perches was the next effective treatment with 0.18 larva/plant and it was found on par with HaNPV (0.19), neem (0.19) and bird perches (0.21). All the treatments were significantly superior to control which recorded the highest larval population (0.32).

##### **Flowering stage**

IPM that received endosulfan as third spray was more effective with the lowest mean number of larvae per plant (0.081) during flowering stage, but endosulfan (0.10) was as effective as IPM treatment. Neem (0.12), HaNPV (0.13) and bird perches (0.14) were on par in managing the large size larvae. Control recorded significantly the highest larval number (0.28).

##### **Pod formation stage**

Larvae per plant during podding stage was the least in IPM (0.15) and HaNPV (0.15). Endosulfan (0.17) was on par with IPM and HaNPV managing large sized larvae. Bird perches (0.19) and neem (0.21) were on par in managing large size larvae but significantly superior over control (0.36).



Table 4 : Efficacy of the treatments in managing large size larvae of *H.armigera* during *rabi* 1998-99

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of larvae per plant)			
Neem 0.006% (AZA 3%)	0.19 (0.4400) <sup>ab</sup>	0.12 (0.3413) <sup>bc</sup>	0.21 (0.4562) <sup>b</sup>	0.05 (0.2235) <sup>a</sup>
HaNPV250LE/ha	0.19 (0.4398) <sup>ab</sup>	0.13 (0.3591) <sup>c</sup>	0.15 (0.3816) <sup>a</sup>	0.06 (0.2369) <sup>a</sup>
Bird perches one/plot	0.21 (0.4608) <sup>b</sup>	0.14 (0.3706) <sup>c</sup>	0.19 (0.4328) <sup>b</sup>	0.08 (0.2849) <sup>a</sup>
Endosulfan 0.07%	0.17 (0.4105) <sup>a</sup>	0.10 (0.3093) <sup>ab</sup>	0.17 (0.4080) <sup>ab</sup>	0.06 (0.2498) <sup>a</sup>
IPM	0.18 (0.4291) <sup>ab</sup>	0.08 (0.2900) <sup>a</sup>	0.15 (0.3816) <sup>a</sup>	0.06 (0.2497) <sup>a</sup>
Control	0.32 (0.5644) <sup>c</sup>	0.28 (0.5257) <sup>d</sup>	0.36 (0.5985) <sup>c</sup>	0.39 (0.6223) <sup>b</sup>
S.Ed.	0.015	0.017	0.023	0.029
CD	0.032	0.037	0.049	0.062

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

### **Preharvest stage**

All the treatments neem (0.05), HaNPV (0.06), IPM (0.06), endosulfan (0.06) and bird perches (0.08) except control were on par and registered uniformly less population but significantly superior to control (0.39) in managing large size larvae at pre harvest stage.

#### **4.1.6 Efficacy of the Treatments on the Total Larval Load of *H.armigera* During *rabi* 1998-99**

In order to assess the efficacy of different IPM components in managing the *H.armigera* larval population, an experiment was conducted and the results are presented in Table .5. The number of larvae in all the experimental plots were recorded at weekly interval and the data were compiled to get the mean number of larvae at different crop stages.

### **Vegetative stage**

The interruptions were made in the respective treatments at 21 DAS and 37 DAS which coincided with vegetative stage of the crop. The results revealed a significant reduction in larval number in the plots treated with endosulfan with the lowest number of (1.58) larvae/plant. The plots treated with HaNPV with 1.78 larvae/plant stood next in the order of efficacy. Neem and IPM which received neem as first spray and HaNPV as second spray were on par (1.85, 2.00 larvae/plant, respectively). The plot with bird perches was the least effective among the treatments with 2.10 larvae/plant but significantly superior over control (2.52).

### **Flowering stage**

During flowering stage the crop received one spray with the respective treatments at 52 DAS. IPM which received endosulfan as third spray was the most effective treatment with the lowest number of larvae per plant

Table 5 : Efficacy of the treatments in managing total larval load of *H.armigera* during *rabi* 1998-99

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of larvae per plant)			
Neem 0.006% (AZA 3%)	1.85 (1.3588) <sup>bc</sup>	2.17 (1.4718) <sup>a</sup>	2.39 (1.5449) <sup>c</sup>	1.70 (1.3036) <sup>d</sup>
HaNPV250LE/ha	1.78 (1.3320) <sup>b</sup>	2.13 (1.4575) <sup>a</sup>	2.22 (1.4900) <sup>b</sup>	1.59 (1.2521) <sup>b</sup>
Bird perches one/plot	2.10 (1.4501) <sup>d</sup>	2.68 (1.6378) <sup>b</sup>	2.34 (1.5300) <sup>bc</sup>	1.68 (1.2965) <sup>cd</sup>
Endosulfan 0.07%	1.58 (1.2560) <sup>a</sup>	1.68 (1.4416) <sup>a</sup>	2.34 (1.5285) <sup>bc</sup>	1.60 (1.2646) <sup>bc</sup>
IPM	2.00 (1.4140) <sup>cd</sup>	1.95 (1.3965) <sup>a</sup>	2.00 (1.4140) <sup>a</sup>	1.31 (1.1426) <sup>a</sup>
Control	2.52 (1.5879) <sup>e</sup>	3.00 (1.7318) <sup>b</sup>	2.89 (1.7006) <sup>d</sup>	2.28 (1.5081) <sup>c</sup>
S.Ed.	0.027	0.046	0.026	0.018
CD	0.056	0.096	0.054	0.038

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

(1.95) but was at a par with endosulfan (2.08), HaNPV (2.13) and neem (2.17). Bird perches was less effective with 2.68 larvae per plant and was on par with control (3.0).

### **Pod formation stage**

The sprays were given at 67 DAS and 84 DAS during pod formation stage of the crop. IPM treatment which received neem as fourth and HaNPV as fifth spray recorded significantly the lowest number of larvae per plant (2.00). HaNPV with 2.22 larvae per plant stood next in the order of efficacy. The plots treated with endosulfan, bird perches and neem (2.34, 2.34, 2.39 larvae/plant respectively) were on par but significantly superior compared to control which recorded the highest number of larvae per plant (2.89).

### **Preharvest stage**

The results revealed a significant reduction in the number of larvae in the plots which received IPM treatment by recording the lowest number (1.31) of larvae per plant. The plots treated with HaNPV and endosulfan were on par and stood next with 1.59, 1.60 larvae per plant respectively. Bird perches (1.68) and neem (1.70) were on par and less effective among the treatments but significantly superior to control (2.28).

#### **4.1.7 Population Fluctuations of *H.armigera* in Chickpea During *rabi* 1999-2000**

Moth activity of *H.armigera* was observed throughout the crop period. Three peaks were observed, with the first peak during the initiation of flowering i.e 47 DAS (14.33 moths/trap), 2<sup>nd</sup> peak at 90 DAS (30.6 moths/trap) and 3<sup>rd</sup> peak at 97 DAS (22.3 moths/trap) (Plate.5 & Figure.2).



Plate 5 : Pheromone trap for recording adult activity of *H. armigera*.

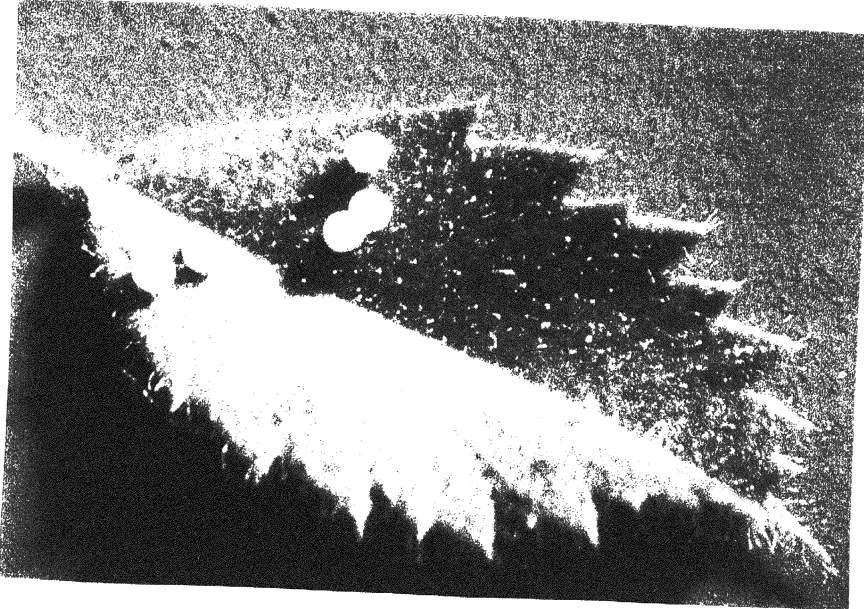


Plate 6 : Eggs of *H. armigera* on chickpea leaf.

During *rabi* 1999-2000 observations on egg population showed an average of 0.29 egg per plant at vegetative stage and there was an increase in the number at flowering stage (0.34 egg/plant) with a peak egg number of 0.48 (Appendix VI) at 54DAS. Later the number reached 0.07 egg per plant by preharvest stage of the crop (Plate.6).

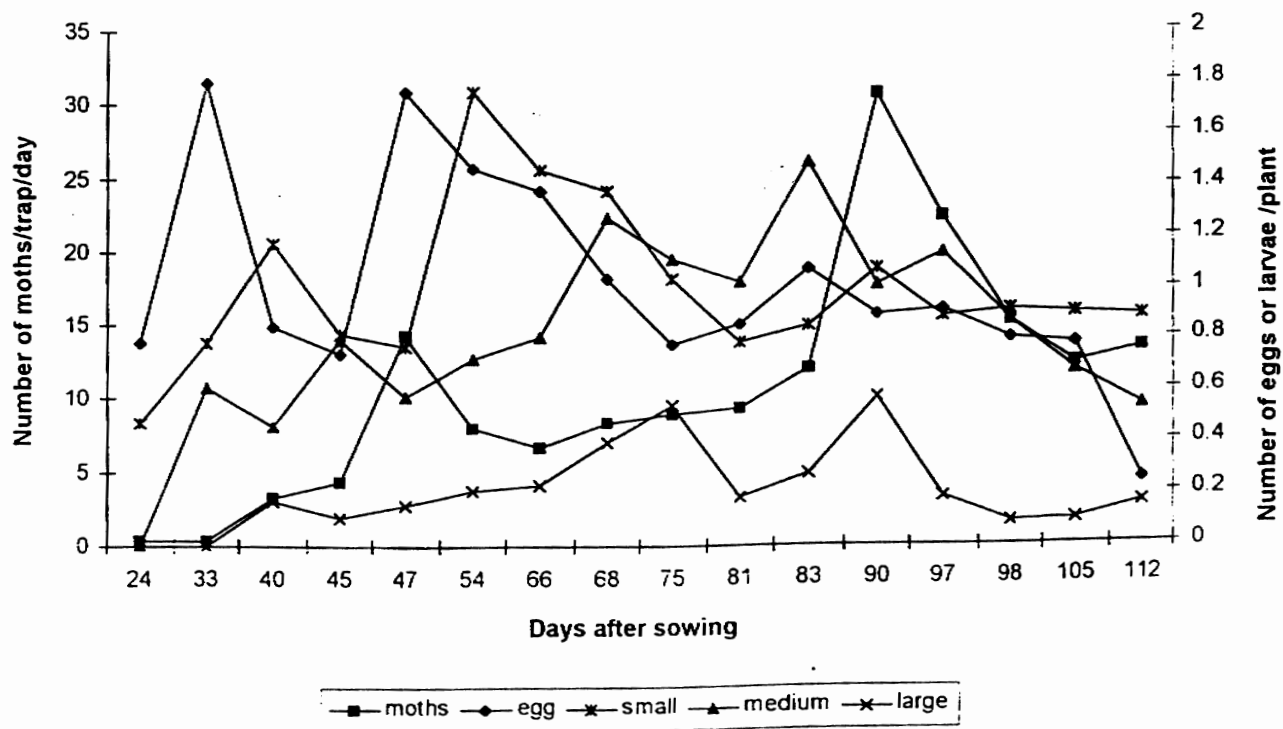
The data on small size larval counts indicated 0.93, 1.33, 1.03 and 0.90 larvae per plant during vegetative, flowering, pod formation and preharvest stages of the crop, respectively with a peak at 54DAS (Appendix.VII).

The medium size larval peak was noticed at 83DAS (Appendix.VIII) which coincided with pod formation stage. The highest number of medium size larvae was observed during pod formation stage (1.18 larvae/plant). The medium size larval population in the other stages of the crop was in the range of 0.63 to 0.81 larva per plant.

The large size larval peak (0.58 larva per plant) was noticed at 90DAS (Appendix IX) which coincided with pod formation stage. The population was 0.10, 0.22, 0.40 and 0.36 larva per plant during vegetative, flowering, pod formation and preharvest stages, respectively.

The data on pooled larval population showed that moderate population (1.65 larvae per plant) was recorded at vegetative stage of the crop and there was gradual increase in the number by flowering stage (2.26 larvae/plant). The population reached peak (2.6 larvae per plant) at pod formation stage and there after the larval number declined slightly to 1.84 larvae per plant by preharvest stage of the crop.

Fig. 2 : Population fluctuations of *H.armigera* during rabi 1999-2000



#### 4.1.8 Efficacy of the Treatments on Oviposition Behaviour of *H.armigera* During *rabi* 1999-2000

In order to assess the efficacy of IPM components on oviposition behaviour of *H. armigera* an experiment was conducted during *rabi* 1999-2000 and the results are presented in Table. 6. The number of eggs were observed at weekly interval and the mean number of eggs per plant at different crop stages were calculated.

##### **Vegetative stage**

The crop received one spray in the respective treatments at 32 DAS during vegetative stage. The plots treated with neem recorded significantly the lowest number of eggs per plant (0.04). The next best was IPM treatment (0.08) which also received neem as first spray. There was no significant difference in the number of eggs recorded in the treatment with HaNPV and endosulfan with 0.16 and 0.20 egg per plant, respectively. Plots with bird perche (0.25) showed no effect and was on par with control (0.29).

##### **Flowering stage**

During flowering stage the interruptions were made in the respective treatments at 47 DAS and at 62 DAS. The results revealed that the highest reduction in egg number was in the plots treated with neem (0.11) which was also on par with endosulfan (0.19). There was no significant difference in the number of eggs recorded between the bird perches, IPM treatment receiving HaNPV as second spray and endosulfan as third spray and HaNPV spray alone (0.22, 0.23, 0.28, respectively). These were also found to be on par with control (0.34).



Table 6 : Effect of the treatments on oviposition behaviour of *H.amigera* during *rabi* 1999-2000

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of eggs per plant)			
Neem 1750 ml/ha (Nivaar 1500 ppm)	0.04 (0.2039) <sup>a</sup>	0.11 (0.3352) <sup>a</sup>	0.03 (0.1741) <sup>a</sup>	0 (0.2236) <sup>a</sup>
HaNPV250LE/ha	0.16 (0.4029) <sup>c</sup>	0.28 (0.5281) <sup>bc</sup>	0.09 (0.3059) <sup>bc</sup>	0.03 (0.2760) <sup>ab</sup>
Bird perches one/plot	0.25 (0.4956) <sup>dn</sup>	0.22 (0.4652) <sup>bc</sup>	0.10 (0.3102) <sup>c</sup>	0.07 (0.3445) <sup>cd</sup>
Endosulfan 0.07%	0.20 (0.4469) <sup>cd</sup>	0.19 (0.4375) <sup>ab</sup>	0.08 (0.2789) <sup>bc</sup>	0.03 (0.2848) <sup>bc</sup>
IPM	0.08 (0.2955) <sup>b</sup>	0.23 (0.4784) <sup>bc</sup>	0.06 (0.2404) <sup>ab</sup>	0 (0.2236) <sup>a</sup>
Control	0.29 (0.5359) <sup>e</sup>	0.34 (0.5806) <sup>c</sup>	0.23 (0.4754) <sup>d</sup>	0.07 (0.3487) <sup>d</sup>
S.Ed.	0.042	0.055	0.032	0.029
CD	0.088	0.116	0.068	0.061

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

### **Pod formation stage**

During pod formation stage the treatments were applied at 78 DAS. The results revealed that the highest reduction in number of eggs was in plots treated with neem (0.03 egg/plant) but it was on par with IPM which received neem as fourth spray with 0.06 egg per plant. There was no significant difference in the number of eggs recorded in endosulfan, HaNPV and bird perches treatments (0.08, 0.09, 0.10, respectively), being on par but were found to be significantly superior compared to control (0.23) in recording less number of eggs per plant.

### **Preharvest stage**

During this stage the crop was sprayed with respective treatments at 94DAS. No egg was recorded in the plots treated with neem and IPM treatment which received HaNPV as 5<sup>th</sup> spray. There was no significant difference between the number of eggs recorded in the HaNPV and endosulfan (0.03 both) which came next in the order. Bird perches (0.07) showed no effect and was found to be on par with control (0.07).

#### **4.1.9 Efficacy of the Treatments on Small Size (first & second instars)**

##### **Larvae of *H.armigera* During *rabi* 1999-2000**

To find the effect of various IPM components individually and in combination for managing small size larvae of *H.armigera*, an experiment was conducted and the pest population was recorded at weekly interval and the mean number of larvae per plant at different crop stages in different treatments were analyzed and presented in Table.7. A total of five sprays were given, one during vegetative (32 DAS), two during flowering (47 & 62 DAS), one during pod formation (78 DAS) and one during preharvest (94 DAS) stages of the crop.

### **Vegetative stage**

Endosulfan gave less than 50% control of small size larvae during vegetative stage with the lowest mean number of larvae per plant (0.47), but HaNPV (0.52) was also as efficient as endosulfan in managing small size larvae. IPM (0.56) which received neem as first spray in addition to bird perches and neem (0.61) were on par and came next in the order of efficacy. Bird perches alone showed no effect (0.90 larva per plant) and was on par with control plot which recorded the highest larval population (0.93).

### **Flowering stage**

Neem was recorded lowest mean number of larvae per plant (0.79) but endosulfan (0.92) and IPM (0.95) which received HaNPV as second spray and endosulfan as third spray were also as effective as neem in managing small larvae. HaNPV recorded 0.97 larva/plant and stood next in the order of efficacy. But bird perches (1.30) showed no effect being on par with control. In control the highest larval population was recorded (1.33).

### **Pod formation stage**

Control and bird perches plots had the highest population i.e., 1.03 and 0.98 larvae per plant, respectively during the pod formation stage. IPM that received neem as fourth spray was superior with the lowest mean number of small larvae during this stage (0.62). Endosulfan (0.67), HaNPV (0.71) and neem (0.73) were also as effective as IPM treatment.

### **Preharvest stage**

IPM plot continued its efficiency in keeping small larvae at the lowest level (0.43 larva per plant). HaNPV (0.52) and endosulfan (0.52) showed

Table 7 : Efficacy of the treatments in managing small size larvae of *H.armigera* during *rabi* 1999-2000

Treatment/ Crop stage	Vegetative	Flowering (Mean number of larvae per plant)	Pod formation	Preharvest
Neem 1750 ml/ha (Nivaar 1500 ppm)	0.61 (0.7821) <sup>c</sup>	0.79 (0.8895) <sup>a</sup>	0.73 (0.8512) <sup>a</sup>	0.54 (0.7329) <sup>b</sup>
HaNPV250LE/ha	0.52 (0.7214) <sup>ab</sup>	0.97 (0.9829) <sup>b</sup>	0.71 (0.8394) <sup>a</sup>	0.52 (0.7177) <sup>ab</sup>
Bird perches one/plot	0.90 (0.9506) <sup>d</sup>	1.30 (1.1381) <sup>c</sup>	0.97 (0.9835) <sup>b</sup>	0.79 (0.8907) <sup>c</sup>
Endosulfan 0.07%	0.47 (0.6829) <sup>a</sup>	0.92 (0.9594) <sup>nb</sup>	0.67 (0.8168) <sup>a</sup>	0.52 (0.7221) <sup>nb</sup>
IPM	0.56 (0.7469) <sup>bc</sup>	0.95 (0.9744) <sup>nb</sup>	0.62 (0.7855) <sup>a</sup>	0.43 (0.6587) <sup>a</sup>
Control	0.93 (0.9638) <sup>d</sup>	1.33 (1.1545) <sup>c</sup>	1.03 (1.0122) <sup>b</sup>	0.90 (0.9488) <sup>c</sup>
S.Ed.	0.028	0.042	0.042	0.032
CD	0.060	0.089	0.088	0.067

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

almost equal efficiency and were on par with IPM. Neem (0.54) came next in the order. Bird perches (0.79) showed no effect and was found to be on par with control (0.90).

#### 4.1.10 Efficacy of the Treatments on Medium Size (third & fourth instars) Larvae of *H.armigera* During *rabi* 1999-2000

To assess the efficacy of different IPM components in managing medium size larvae of *H.armigera*, an experiment was conducted and the number of larvae per plant were recorded at weekly interval. The mean number of larvae per plant in different treatments at various crop stages were calculated and presented in Table.8.

##### **Vegetative stage**

The crop was sprayed with the respective treatments by 32 DAS which coincided with vegetative stage. The results revealed that the highest reduction in the number of larvae was in the plots treated with HaNPV (0.33). IPM (0.34) and neem (0.36) were also found to be statistically on par with HaNPV. Endosulfan (0.38) stood next in the order of efficacy. Bird perches (0.55) was the least effective among the treatments but significantly superior over control (0.63).

##### **Flowering stage**

During flowering stage the crop received two sprays at 47 & 62 DAS. IPM treatment which received HaNPV as second spray and endosulfan as third spray recorded the lowest number of larvae per plant (0.20) but it was on par with HaNPV with 0.23 larva per plant. The number of larvae per plant in the treatments endosulfan and neem were found to be on par (0.25, 0.29, respectively) and stood next. Bird perches with 0.48 larva per plant was the least effective among the treatments but significantly superior compared to control (0.71).

Table 8 : Efficacy of the treatments in managing medium size larvae of *H. armigera* during *rabi* 1999-2000

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	Mean number of larvae per plant			
Neem 1750 ml/ha (Nivaar 1500 ppm)	0.36 (0.6018) <sup>ab</sup>	0.29 (0.5400) <sup>c</sup>	0.58 (0.7580) <sup>ab</sup>	0.32 (0.5642) <sup>b</sup>
HaNPV250LE/ha	0.33 (0.5735) <sup>a</sup>	0.23 (0.4741) <sup>ab</sup>	0.54 (0.7315) <sup>a</sup>	0.26 (0.5120) <sup>ab</sup>
Bird perches one/plot	0.55 (0.7415) <sup>c</sup>	0.48 (0.6920) <sup>d</sup>	0.95 (0.9719) <sup>c</sup>	0.74 (0.8580) <sup>d</sup>
Endosulfan 0.07%	0.38 (0.6188) <sup>b</sup>	0.25 (0.5039) <sup>bc</sup>	0.66 (0.8121) <sup>b</sup>	0.57 (0.7539) <sup>c</sup>
IPM	0.34 (0.5849) <sup>ab</sup>	0.20 (0.4414) <sup>a</sup>	0.60 (0.7760) <sup>ab</sup>	0.23 (0.4838) <sup>a</sup>
Control	0.63 (0.7902) <sup>d</sup>	0.71 (0.8404) <sup>e</sup>	1.18 (1.0872) <sup>d</sup>	0.81 (0.8977) <sup>d</sup>
S.Ed.	0.021	0.029	0.028	0.029
CD	0.045	0.062	0.059	0.062

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

### **Pod formation stage**

The crop was sprayed with the respective treatments at 78 DAS coinciding with pod formation stage. The results revealed that the highest reduction in the number of larvae was in the plots treated with HaNPV (0.54 larva per plant) but it was at a par with neem and IPM treatments which received neem as fourth spray, with 0.58, 0.60 larva/plant, respectively. Endosulfan treatment (0.66) stood next in the order of efficacy. Bird perches (0.95) showed little but significantly superior to control (1.18).

### **Preharvest stage**

The crop was sprayed with the respective treatments by 94 DAS during preharvest stage. IPM was the most effective treatment with the lowest number of larvae per plant (0.23). HaNPV with 0.26 larva per plant was as effective as IPM. Neem treatment (0.32) came next in the order. Endosulfan (0.57) although less effective compared to the earlier treatments, was significantly superior to bird perches which showed no effect (0.74) and was found to be on par with control (0.81).

#### **4.1.11 Effect of the Treatments on Large Size (fifth & sixth instar)**

##### **Larvae of *H.armigera* During *rabi* 1999-2000**

The effect of IPM components individually and in combination in managing large size larvae of *H.armigera*, was evaluated during 1999-2000. Five sprays were given, one at vegetative stage, two at flowering stage, one at podding and one at preharvest stage. The larval population was observed at weekly interval and the mean number of larvae per plant in different treatments at different stages was assessed and presented in Table 9.

### **Vegetative stage**

For managing large size larvae HaNPV was found to be the most effective with the least number of larvae per plant (0.03) but was on par with bird perches (0.04). Birds activity was more during this stage (Table 10). IPM plots that received neem as first spray (0.058) and neem (0.058) and endosulfan (0.06) were being on par and registered significantly low late instar larval population compared to control (0.10).

### **Flowering stage**

IPM plots that received HaNPV as second spray and endosulfan as third spray and HaNPV recorded lowest number of large size larvae (0.02). Neem stood next in the order of efficacy with 0.03 larva per plant. Endosulfan (0.06) and bird perches (0.08) were found to be on par and significantly superior compared to control (0.22).

### **Pod formation stage**

IPM that received neem as fourth spray continued its efficiency in managing large size larvae (0.26), however it was found on par with endosulfan (0.27), HaNPV (0.27) and bird perches (0.28). Neem with 0.30 larva per plant came closely behind and was significantly superior to control (0.40).

### **Preharvest stage**

IPM that received HaNPV as fifth spray was superior in managing large size larvae with 0.02 larva per plant but was on par with HaNPV (0.04) and bird perches (0.05). Endosulfan (0.09) and neem (0.13) were on par and came next in the order of efficacy and were significantly superior over control (0.36).



Table 9: Efficacy of the treatments in managing large size larvae of *H.armigera* during *rabi* 1999-2000

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of larvae per plant)			
Neem 1750 ml/ha (Nivaar 1500 ppm)	0.58 (0.3289) <sup>bc</sup>	0.03 (0.2885) <sup>bc</sup>	0.30 (0.5470) <sup>b</sup>	0.13 (0.4256) <sup>c</sup>
HaNPV250LE/ha	0.03 (0.2885) <sup>a</sup>	0.02 (0.2660) <sup>ab</sup>	0.27 (0.5189) <sup>ab</sup>	0.04 (0.3009) <sup>ab</sup>
Bird perches one/plot	0.04 (0.2956) <sup>ab</sup>	0.08 (0.3534) <sup>d</sup>	0.28 (0.5331) <sup>ab</sup>	0.05 (0.3210) <sup>ab</sup>
Endosulfan 0.07%	0.06 (0.3353) <sup>c</sup>	0.06 (0.3353) <sup>cd</sup>	0.27 (0.5188) <sup>ab</sup>	0.09 (0.3758) <sup>bc</sup>
IPM	0.06 (0.3289) <sup>bc</sup>	0.02 (0.2234) <sup>a</sup>	0.26 (0.5092) <sup>a</sup>	0.02 (0.2678) <sup>a</sup>
Control	0.10 (0.3817) <sup>d</sup>	0.22 (0.5229) <sup>u</sup>	0.40 (0.6301) <sup>c</sup>	0.36 (0.8764) <sup>d</sup>
S.Ed.	0.016	0.025	0.017	0.037
CD	0.035	0.052	0.037	0.079

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

Table 10 : List of birds observed in the chickpea field-their identification and habits

Sl.No.	Common Name	Scientific Name	Food Habits	Remarks
1	Black Drongo/King Crow	<i>Dicrurus adismilis</i> (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	<i>Coracias benghalensis</i> (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	<i>Bubulcus ibis</i> (Lin.)	Chiefly grasshoppers, blue bottles, cicadas and caterpillars; also frogs, lizards, fish etc.	Highly beneficial in both dry and wet agro ecosystems
4	Paddy Field Pipit	<i>Anthus novaeseelandiae</i> (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	<i>Hirundo rustica</i> (Lin.)	Hawks winged insects high up in air or close to the ground.	Beneficial to agriculture.
6	Indian Myna	<i>Acridotheres tristis</i> (Lin.)	Omnivorous. Eats fruits, insects, kitchen scraps.	Follows the plough for insects, pupae, etc.
7	Red Winged Bush Lark	<i>Mirafa erythroptera</i> (Blyth)	Seeds of grass and weeds, insects.	Beneficial to Agriculture.
8	Red Wattled Lapwing	<i>Vanellus indicus</i> (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	<i>Aegithina tiphia</i> (Lin.)	Insects, grubs, mollusks, etc..	Arboreal. affects village outskirts and secondary jungle. Beneficial in agriculture and horticulture.
10	Baya Weaver Bird	<i>Ploceus hilippinus</i> (Lin.)	Gleans paddy and other grain-harvested fields. Also eats insects.	Seen abundantly in ICRISAT, Patancheru campus. Beneficial in insect pest control

#### 4.1.12 Efficacy of the Treatments on the Total Larval Load of *H.armigera* During *rabi* 1999-2000

To assess the effect of different IPM components in managing *H.armigera* larval population on chickpea, an experiment was conducted with six treatments. The number of larvae were recorded at weekly interval in different experimental plots. The mean number of larvae of all stages per plant in different treatments during different crop stages was calculated and presented in Table 11.

##### **Vegetative stage**

The crop received one spray with the respective treatments by 32 DAS during vegetative stage. The results revealed the highest reduction in the number of larvae in the plots treated with HaNPV (0.88) but it was on par with endosulfan (0.91). IPM which received neem as first spray in addition to bird perch with 0.94 larva per plant, came next and was found to be significantly superior to the remaining treatments. Next were neem (1.02) and bird perches (1.05) being on par and gave significantly superior control of *H.armigera* larvae compared to control plots (1.65).

##### **Flowering stage**

The crop received two sprays at 47 & 62 DAS during flowering stage. IPM (1.21 larvae/ plant) which received HaNPV as second spray and endosulfan as third spray, HaNPV (1.21 larvae/plant), and endosulfan (1.24 larvae/plant) were the best effective treatments being on par and significantly superior to the remaining treatments. Neem stood next with 1.33 larvae per plant in the order of efficacy. Bird perch was the least effective with 1.85 larvae per plant among the treatments but it was significantly superior compared to control which recorded 2.26 larvae per plant.

Table 11 : Efficacy of the treatments in managing total larval load of *H.armigera* during *rabi* 1999-2000

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of larvae per plant)			
Neem 1750 ml/ha (Nivaar 1500 ppm)	1.02 (1.0101) <sup>c</sup>	1.33 (1.1545) <sup>b</sup>	1.60 (1.2644) <sup>b</sup>	0.90 (0.9501) <sup>b</sup>
HaNPV250LE/ha	0.88 (0.9397) <sup>a</sup>	1.21 (1.1009) <sup>a</sup>	1.51 (1.2284) <sup>a</sup>	0.82 (0.9047) <sup>b</sup>
Bird perches one/plot	1.05 (1.0225) <sup>c</sup>	1.85 (1.3600) <sup>c</sup>	2.20 (1.4820) <sup>c</sup>	1.58 (1.2585) <sup>d</sup>
Endosulfan 0.07%	0.91 (0.9550) <sup>ab</sup>	1.24 (1.1122) <sup>a</sup>	1.60 (1.2634) <sup>b</sup>	1.17 (1.0808) <sup>c</sup>
IPM	0.94 (0.9786) <sup>b</sup>	1.21 (1.1001) <sup>a</sup>	1.48 (1.2160) <sup>a</sup>	0.69 (0.8307) <sup>a</sup>
Control	1.65 (1.2843) <sup>d</sup>	2.26 (1.5044) <sup>d</sup>	2.60 (1.6135) <sup>d</sup>	1.84 (1.3552) <sup>e</sup>
S.Ed.	0.011	0.019	0.016	0.025
CD	0.024	0.041	0.034	0.053

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

### Pod formation stage

The crop was sprayed with the respective treatments by 78 DAS coinciding with pod formation stage. IPM which received neem as fourth spray and HaNPV were on par and significantly superior to the rest of the treatments in managing *H.armigera* larvae with 1.48 and 1.51 larvae per plant. Endosulfan (1.60 larvae/plant) and neem (1.60 larvae/plant) were on par and stood next in the order of efficacy. Bird perches (2.20) was less effective but significantly superior compared to control which recorded the highest mean number of larvae per plant (2.60).

### Preharvest stage

The crop received one spray at 94 DAS during the preharvest stage. IPM treatment which received HaNPV as fifth spray was the most effective with the highest reduction in larval population during this stage (0.69). HaNPV with 0.82 larva per plant and neem with 0.90 larva per plant were on par and stood next in the order of efficacy and significantly superior compared to endosulfan (1.17). Bird perches was the least effective with 1.58 larvae per plant among the treatments but significantly superior compared to control which recorded 1.84 larvae per plant.

#### 4.1.13 Mean Efficacy of the Treatments on Oviposition Behaviour of *H.armigera* in chickpea During Two Years

The mean data computed on oviposition behaviour of *H.armigera* during two years are presented in Table.12 (Figure.3).

### Vegetative stage

The plots treated with neem recorded the lowest number of eggs per plant (0.35) during vegetative stage but it was on par with IPM (0.39) which received neem as first spray. The treatments HaNPV and endosulfan were on par and stood next with less number of eggs (0.49, 0.52 egg/

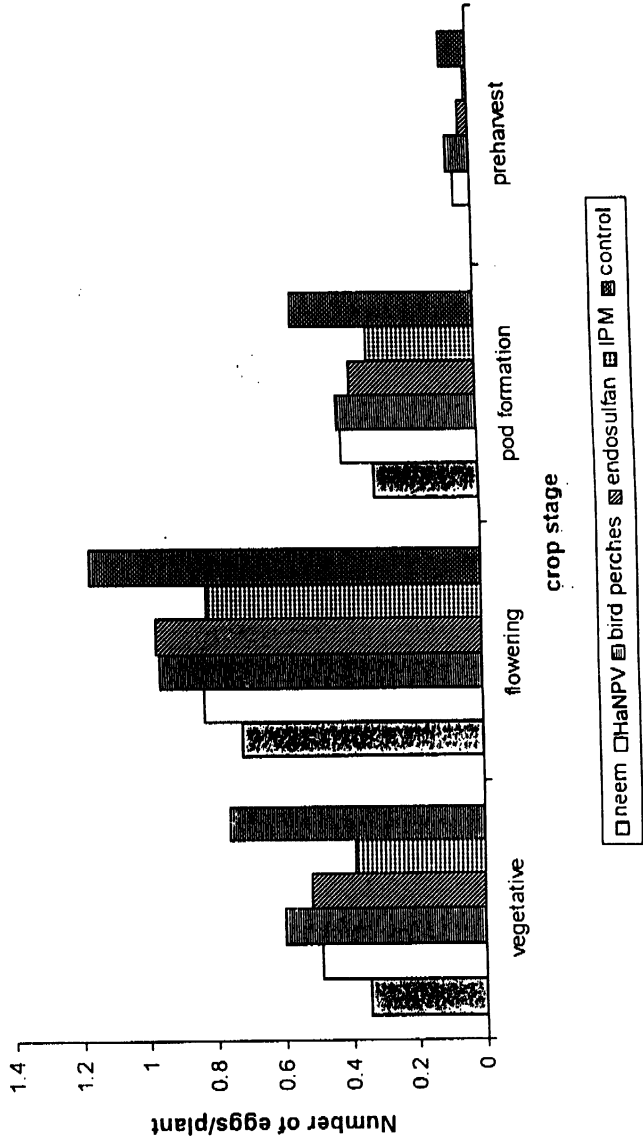
Table 12: Mean efficacy of the treatments on oviposition behaviour of *H. armigera*

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of eggs per plant)			
Neem	0.35 (0.5874) <sup>a</sup>	0.72 (0.8485) <sup>a</sup>	0.31 (0.5522) <sup>a</sup>	0 (0.2236) <sup>a</sup>
HaNPV250LE/ha	0.49 (0.7000) <sup>bc</sup>	0.83 (0.9082) <sup>b</sup>	0.41 (0.6403) <sup>c</sup>	0.05 (0.3162) <sup>bc</sup>
Bird perches one/plot	0.60 (0.7714) <sup>cd</sup>	0.96 (0.9772) <sup>c</sup>	0.42 (0.6442) <sup>c</sup>	0.07 (0.3391) <sup>c</sup>
Endosulfan 0.07%	0.52 (0.7211) <sup>c</sup>	0.97 (0.9823) <sup>c</sup>	0.38 (0.6164) <sup>bc</sup>	0.03 (0.2738) <sup>ab</sup>
IPM	0.39 (0.6204) <sup>ab</sup>	0.82 (0.9027) <sup>ab</sup>	0.32 (0.5656) <sup>ab</sup>	0.01 (0.2345) <sup>a</sup>
Control	0.76 (0.8689) <sup>d</sup>	1.17 (1.0793) <sup>d</sup>	0.55 (0.7416) <sup>d</sup>	0.08 (0.3505) <sup>c</sup>
S.Ed.	0.046	0.027	0.030	0.028
CD	0.098	0.058	0.063	0.059

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

Fig 3: Mean effect of the treatments on oviposition of *H. armigera* in chickpea.



plant, respectively). Bird perches (0.60) showed poor efficacy and was found on par with control (0.76 egg/plant).

### **Flowering stage**

During flowering stage also neem (0.72) was found superior in keeping the egg number at low level. IPM and HaNPV (0.82, 0.83 eggs/plant, respectively) were found on par in reducing the oviposition. Bird perches and endosulfan plots (0.96, 0.97 egg/plant, respectively) were on par and recorded significantly reduced egg number compared to control (1.17 eggs/plant).

### **Pod formation**

Neem and IPM which received neem as first and fourth spray were on par and recorded the lowest number of eggs/plant (0.31, 0.32 egg/plant, respectively). All the remaining treatments Viz., endosulfan (0.38), HaNPV (0.41) and bird perches (0.42) were on par and recorded significantly less number of eggs compared to control.

### **Preharvest stage**

During this period also neem treatment (0) provided maximum repellency for *H.armigera* oviposition. IPM (0.01) and endosulfan (0.03) treatments were also on par with neem and recorded less number of eggs. HaNPV (0.05) and bird perches (0.07) were on par with control treatment (0.08)

#### **4.1.14 Mean Efficacy of the Treatments Against Small Size Larvae of *H.armigera* in Chickpea During Two Years**

The mean data of the two years on the effect of different IPM components on small size larvae of *H.armigera* are presented in Table 13 (Figure 4).



**Vegetative stage**

The data revealed that during this stage the plots sprayed with endosulfan recorded the lowest number of larvae per plant (0.69). The treatments HaNPV (0.81) and IPM (0.84) were also as effective as endosulfan. Neem (0.90) was found next in the order of efficacy. Bird perches (1.08) showed no effect on small size larval population and was on par with control (1.20).

**Flowering**

During this stage neem (1.11), IPM (1.12), endosulfan (1.13) and HaNPV (1.18) were on par and recorded significantly less number of larvae compared to the remaining two treatments. Bird perches (1.57) showed no effect in managing small size larvae and was on par with control (1.61).

**Pod formation stage**

IPM treatment (0.89 larva/plant) was the most effective with the lowest number of larvae per plant. HaNPV (0.97) and endosulfan (1.00) and neem (1.01) came next and were on par and found to be significantly superior over the remaining treatments. Bird perches (1.16) showed no effect and was on par with control (1.26).

**Preharvest stage**

Based on the results, IPM proved significantly superior in keeping the larval population at the lowest level with 0.35 larva/plant. Endosulfan (0.73), HaNPV (0.74), neem (0.76) and bird perches (0.90) were on par and significantly superior over control which recorded the highest larval number (1.08).

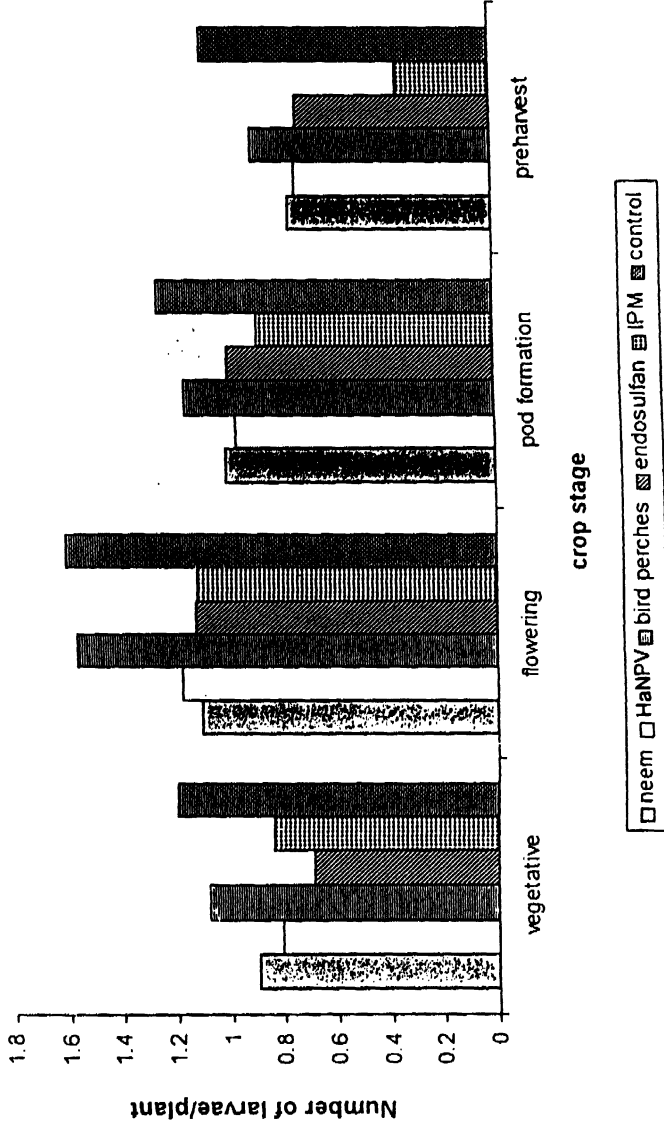
Table 13: Mean efficacy of the treatments on small size larvae of *H. armigera*

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of larvae per plant)			
Neem	0.90 (0.9460) <sup>b</sup>	1.11 (1.0535) <sup>a</sup>	1.01 (1.0024) <sup>b</sup>	0.76 (0.8689) <sup>b</sup>
HaNPV250LE/ha	0.81 (0.8972) <sup>ab</sup>	1.18 (1.0839) <sup>a</sup>	0.97 (0.9848) <sup>ab</sup>	0.74 (0.8573) <sup>b</sup>
Bird perches one/plot	1.08 (1.0368) <sup>c</sup>	1.57 (1.2529) <sup>b</sup>	1.16 (1.0747) <sup>c</sup>	0.90 (0.9460) <sup>bc</sup>
Endosulfan 0.07%	0.69 (0.8306) <sup>n</sup>	1.13 (1.0630) <sup>n</sup>	1.00 (0.9874) <sup>nh</sup>	0.73 (0.8544) <sup>b</sup>
IPM	0.84 (0.9165) <sup>nb</sup>	1.12 (1.0583) <sup>n</sup>	0.89 (0.9433) <sup>n</sup>	0.35 (0.5916) <sup>n</sup>
Control	1.20 (1.0954) <sup>c</sup>	1.61 (1.2668) <sup>b</sup>	1.26 (1.1224) <sup>c</sup>	1.08 (1.0368) <sup>c</sup>
S.Ed.	0.042	0.042	0.028	0.045
CD	0.088	0.089	0.059	0.095

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

Fig 4: Mean effect of the treatments in managing small size larvae of *H. armigera* in chickpea.



#### 4.1.15 Mean Efficacy of the Treatments Against Medium Size Larvae of *H.armigera* in Chickpea During Two Years

The data on cumulative effect of different IPM components on medium size larvae of *H.armigera* during both the years are presented in Table 14 (Figure.5).

##### **Vegetative stage**

HaNPV treated plot was superior in managing the medium size larvae with 0.41 larva/plant however it was found on par with neem with 0.42 larva/plant and IPM with 0.45 larva/plant. Endosulfan (0.47) stood next in the order of efficacy. Bird perches also showed significant reduction in medium size larvae (0.59) compared to control (0.71).

##### **Flowering stage**

During this stage IPM (0.39) was the most effective treatment with the lowest number of larvae/plant. HaNPV (0.43), endosulfan (0.45) and neem (0.46) were on par and significantly superior over the remaining two treatments in managing medium size larvae. Bird perches plot also gave significantly reduced number of larvae per plant (0.60) compared to control (0.80).

##### **Pod formation stage**

IPM was more efficient in managing medium size larvae with 0.64 larva/plant. HaNPV with 0.69 larva/plant was as effective as IPM. Neem (0.74 and endosulfan (0.78) were in turn on par with HaNPV and stood next in the order of efficacy. Bird perches plot also gave a significant reduction in the number of larvae per plant (0.88) compared to control (1.09).

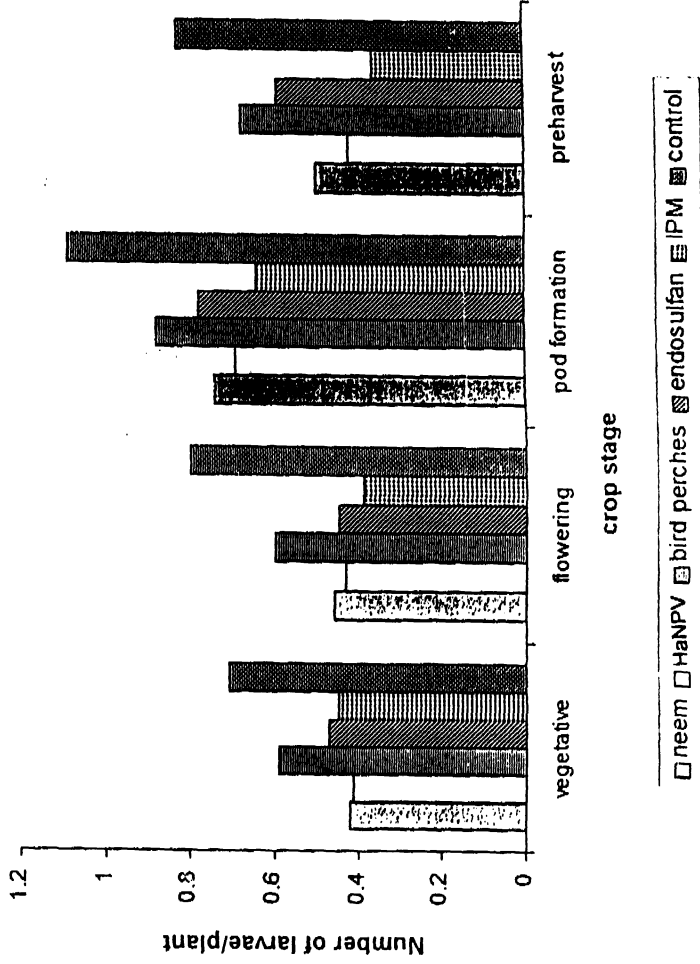
Table 14: Mean efficacy of the treatments on medium size larvae of *H. armigera*

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
Mean number of larvae per plant				
Neem	0.42 (0.6480) <sup>a</sup>	0.46 (0.6745) <sup>b</sup>	0.74 (0.8602) <sup>b</sup>	0.50 (0.7071) <sup>b</sup>
HaNPV250LE/ha	0.41 (0.6403) <sup>a</sup>	0.43 (0.6519) <sup>ab</sup>	0.69 (0.8276) <sup>ab</sup>	0.42 (0.6480) <sup>a</sup>
Bird perches one/plot	0.59 (0.7648) <sup>c</sup>	0.60 (0.7745) <sup>c</sup>	0.88 (0.9380) <sup>c</sup>	0.68 (0.8215) <sup>d</sup>
Endosulfan 0.07%	0.47 (0.6855) <sup>b</sup>	0.45 (0.6670) <sup>b</sup>	0.78 (0.8803) <sup>b</sup>	0.59 (0.7681) <sup>c</sup>
IPM	0.45 (0.6708) <sup>ab</sup>	0.39 (0.6244) <sup>a</sup>	0.64 (0.8000) <sup>a</sup>	0.36 (0.6000) <sup>a</sup>
Control	0.71 (0.8426) <sup>d</sup>	0.80 (0.8944) <sup>d</sup>	1.09 (1.0440) <sup>d</sup>	0.83 (0.9082) <sup>d</sup>
S.Ed.	0.015	0.018	0.020	0.024
CD	0.033	0.038	0.053	0.051

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

Fig 5: Mean effect of the treatments in managing medium size larvae of *H. armigera* in chickpea.



### Preharvest stage

At preharvest stage also IPM (0.36) showed its efficiency in managing the medium size larvae. But HaNPV with 0.42 larva/plant was also as effective as IPM. Neem (0.50) came next and was significantly superior compared to endosulfan (0.59). Bird perches plot also gave a significant reduction in number of larvae per plant (0.68) compared to control (0.83).

#### 4.1.16 Mean efficacy of the Treatments Against Large Size Larvae of *H.armigera* in Chickpea During Two Years

The data on cumulative effect of different IPM components on large size larvae of *H.armigera* during both years are presented in Table.15 (Figure 6).

### Vegetative stage

HaNPV showed better effect in controlling large size larvae with 0.11 larva/plant during vegetative stage. Endosulfan and IPM were on par and stood next in the order of efficacy with 0.12 larva/plant. Neem (0.12) and bird perches (0.13) came next and found to be significantly superior over control (0.21).

### Flowering stage

IPM was the most effective with 0.05 larva/plant and significantly superior compared to other treatments in managing large size larvae. HaNPV (0.08), neem (0.08) and endosulfan (0.08) were on par and stood next in the order of efficacy. Bird perches was the least effective (0.11) but significantly superior over control (0.25).

Table 15: Mean efficacy of the treatments on large size larvae of *H. armigera*

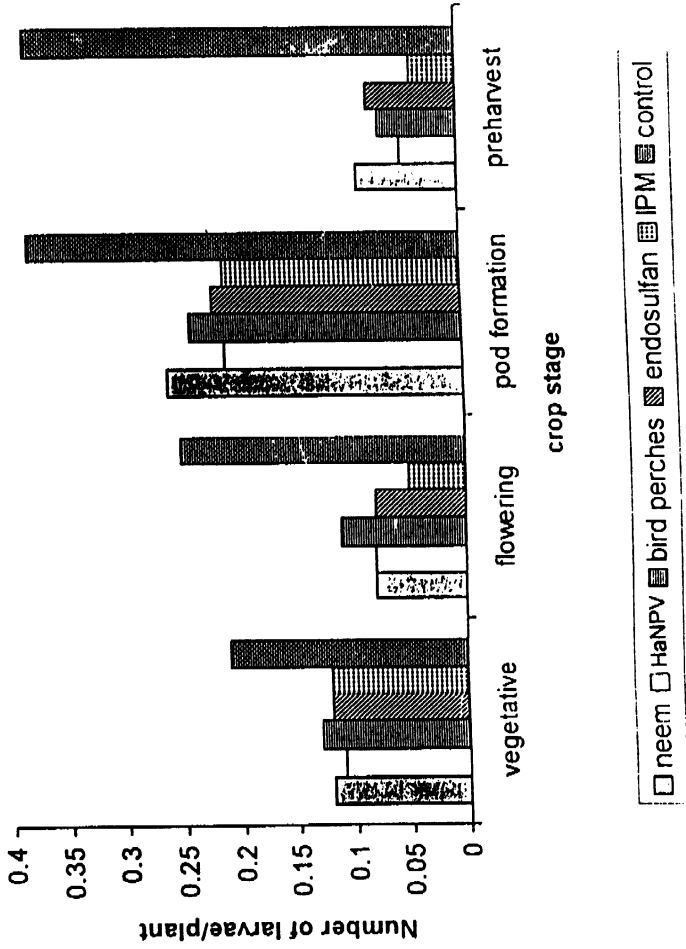
Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of larvae per plant)			
Neem	0.12 (0.3521) <sup>c</sup>	0.08 (0.2738) <sup>b</sup>	0.26 (0.5049) <sup>c</sup>	0.09 (0.30) <sup>c</sup>
HaNPV250LE/ha	0.11 (0.3316) <sup>a</sup>	0.08 (0.2737) <sup>b</sup>	0.21 (0.4582) <sup>ab</sup>	0.05 0.2236) <sup>ab</sup>
Bird perches one/plot	0.13 (0.3535) <sup>c</sup>	0.11 (0.3316) <sup>c</sup>	0.24 (0.4847) <sup>bc</sup>	0.07 (0.2549) <sup>bc</sup>
Endosulfan 0.07%	0.12 (0.3391) <sup>ab</sup>	0.08 (0.2828) <sup>b</sup>	0.22 (0.4690) <sup>nb</sup>	0.08 (0.2738) <sup>bc</sup>
IPM	0.12 (0.3449) <sup>bc</sup>	0.05 (0.2236) <sup>a</sup>	0.21 (0.4527) <sup>a</sup>	0.04 (0.2000) <sup>a</sup>
Control	0.21 (0.4582) <sup>d</sup>	0.25 (0.5000) <sup>d</sup>	0.38 (0.6164) <sup>d</sup>	0.38 (0.6123) <sup>d</sup>
S.Ed.	0.006	0.011	0.013	0.025
CD	0.013	0.035	0.029	0.052

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant



Fig 6: Mean effect of the treatments in managing large size larvae of *H. armigera* in chickpea.



### **Pod formation stage**

IPM was once again proved more effective with the lowest number of larvae per plant (0.21) during this stage, however it was found on par with HaNPV (0.21) and endosulfan (0.22). Bird perches (0.24) and neem (0.26) were on par and significantly superior over control (0.38) in managing large size larval population at pod formation stage.

### **Preharvest stage**

IPM continued its superiority in managing large size larvae during this stage also with 0.04 larva/plant and was on par with HaNPV (0.05). Bird perches (0.07), endosulfan (0.08) and neem (0.09) were next being on par and significantly superior to control which recorded the highest larval population (0.38).

#### **4.1.17 Mean efficacy of The Treatments Against the Total Larval Load of *H.armigera* in Chickpea During Two Years**

Data on the mean effect of different IPM components in managing total larval load are presented in Table 16 (Figure 7).

### **Vegetative stage**

The results (Table 15) revealed a significant reduction in larval number in the plots treated with endosulfan (1.25) and HaNPV (1.33) (Plate 7). Neem (1.44) and IPM (1.47) which received neem as first spray were on par and stood next in the order of efficacy. Bird perches was less effective with 1.58 larvae/plant but significantly superior over control (2.09).

### **Flowering stage**

IPM was significantly the most effective treatment with 1.58 larvae/plant. Endosulfan (1.66) and HaNPV (1.67) stood next and were on par

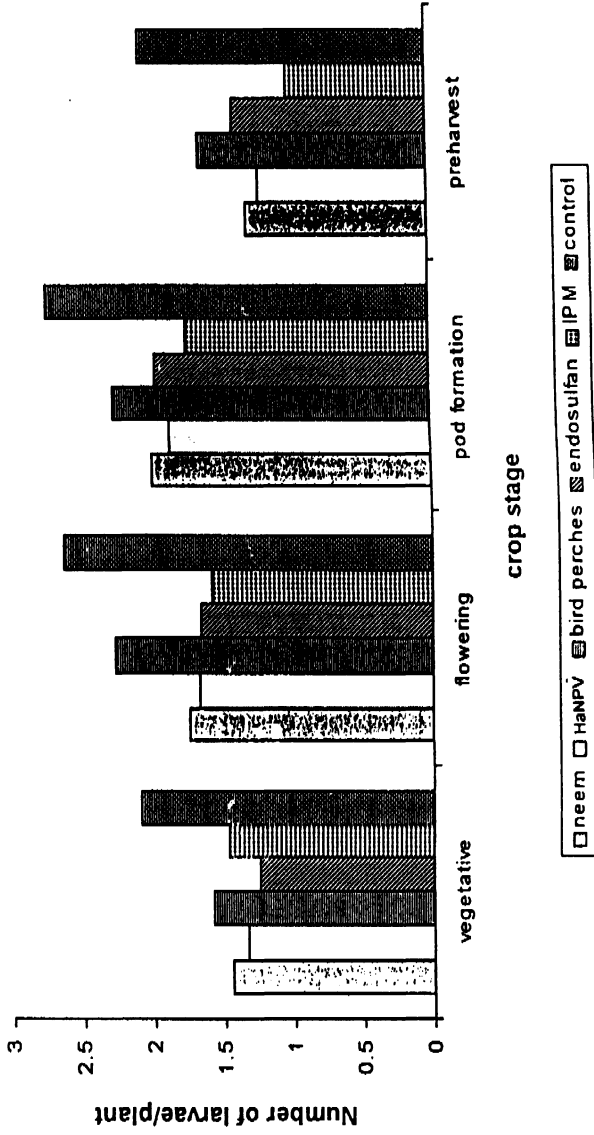
Table 16: Mean efficacy of the treatments on total larval load of *H. armigera*

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	Mean number of larvae per plant			
Neem	1.44 (1.1979) <sup>b</sup>	1.75 (1.3228) <sup>c</sup>	2.00 (1.4124) <sup>b</sup>	1.30 (1.1401) <sup>b</sup>
HaNPV250LE/ha	1.33 (1.1532) <sup>a</sup>	1.67 (1.2922) <sup>b</sup>	1.87 (1.3656) <sup>ab</sup>	1.21 (1.0977) <sup>b</sup>
Bird perches one/plot	1.58 (1.2549) <sup>c</sup>	2.27 (1.5049) <sup>d</sup>	2.27 (1.5066) <sup>c</sup>	1.63 (1.2767) <sup>c</sup>
Endosulfan 0.07%	1.25 (1.1157) <sup>a</sup>	1.66 (1.2884) <sup>b</sup>	1.97 (1.4035) <sup>b</sup>	1.39 (1.1768) <sup>b</sup>
IPM	1.47 (1.2124) <sup>b</sup>	1.58 (1.2569) <sup>a</sup>	1.74 (1.3190) <sup>a</sup>	1.00 (0.9998) <sup>a</sup>
Control	2.09 (1.4439) <sup>d</sup>	2.63 (1.6217) <sup>e</sup>	2.75 (1.6568) <sup>d</sup>	2.06 (1.4352) <sup>d</sup>
S.Ed.	0.019	0.011	0.025	0.046
CD	0.041	0.024	0.053	0.096

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

Fig 7: Mean effect of the treatments in managing total larvae load of *H. armigera* in chickpea.



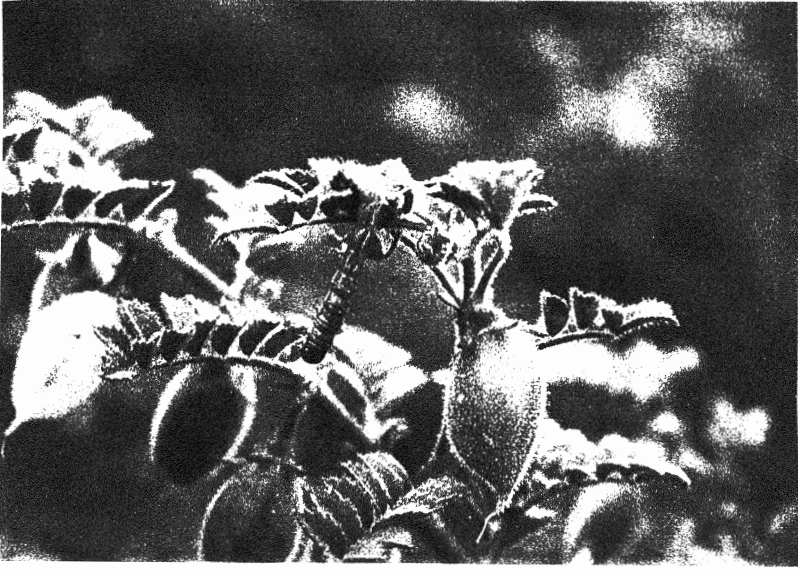


Plate 7: HaNPV infected larvae of *H. armigera* in chickpea.



Plate 8: Natural incidence of larval parasitoid *Camponotus chlorideae* Uchida.

and significantly superior compared to neem (1.75). Bird perches was the least effective with 2.27 larvae/plant among the treatments but significantly superior over control (2.63).

### **Pod formation stage**

IPM was once again the most effective with the lowest number of larvae per plant (1.74). HaNPV with 1.87 larvae/plant was found on par with IPM. Endosulfan (1.97) and neem (2.00) were on par and stood next in the order of efficacy. Bird perches (2.27) was the least effective but significantly superior over control which recorded high larval load (2.75).

### **Preharvest stage**

IPM maintained its superiority during this stage also with 1.00 larvae/plant being the most effective and significantly superior to all the remaining treatments. HaNPV (1.21), neem (1.30) and endosulfan (1.39) were on par and stood next in the order. Bird perches was the least effective treatment with 1.03 larvae/plant but significantly superior over control (2.06).

## **4.2 EFFECT OF THE TREATMENTS ON NATURAL ENEMIES PRESENT IN CHICKPEA ECOSYSTEM**

### **4.2.1 Effect of the Treatments on Soil Inhabiting Natural Enemies During *rabi* 1998-99**

In order to assess the effect of different IPM components on soil inhabiting natural enemies, an experiment was conducted during *rabi* 1998-99 season and the results are presented in Table.17 (Figure.8). The number of natural enemies was observed in pitfall traps at ten days interval. Natural enemies such as ants, braconid wasps, ichneumonid wasps (Hymenoptera), ground beetles, coccinellids (Coleoptera), crickets (Orthoptera), earwigs (Dermaptera) and spiders were

collected from the pitfall traps fixed in each treatment. A total of five sprays, two during vegetative, one during flowering and two during pod formation stage were given. The mean number of natural enemies present in different treatments was calculated.

### **Vegetative stage**

During the vegetative stage the plots treated with endosulfan recorded significantly less number of natural enemies (136.5 natural enemies/ trap). The plots treated with neem, IPM which received neem as first spray stood next with lowest number of natural enemies (245.8, 244.6 natural enemies/ trap, respectively). HaNPV (385.6/trap) and bird perches (331.5/trap) did not show any significant effect on natural enemies and were on par with control (380.0/trap).

### **Flowering stage**

At flowering stage also endosulfan showed toxic effect on natural enemies present on ground (115.8/trap) and recorded the lowest number of natural enemies. Neem also affected the natural enemies (230.4/trap) followed by IPM (231.9/trap) that received endosulfan as third spray. Bird perches (302.8/trap) showed little but not significant effect on ground dwelling natural enemies compared to control. HaNPV (572.8/trap) and control (513.0/trap) were found to be on par.

### **Pod formation stage**

During podding stage also endosulfan was found toxic to ground inhabiting natural enemies up to 70% (40.8/trap) compared to control. Neem also reduced up to 50.5% (69.3/trap) of natural enemies compared to control. IPM that received neem as fourth spray and HaNPV as fifth spray reduced natural enemies up to 25% (104.6/trap) but not statistically

Table 17: Effect of the treatments on soil inhabiting natural enemies in chickpea during *rabi* 1998-1999.

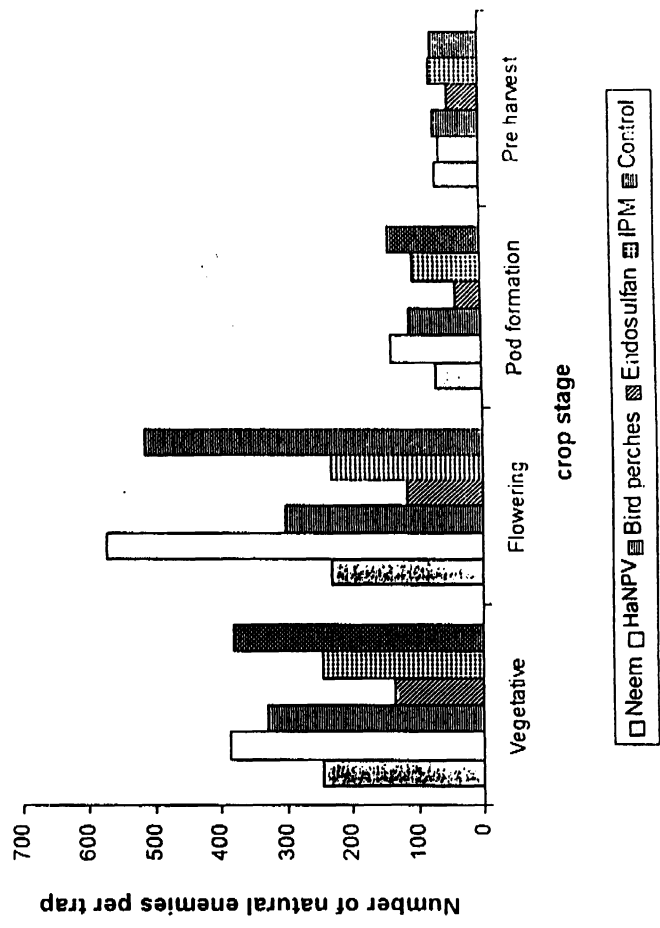
Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of natural enemies/trap)			
Neem 0.006% (AZA 3%)	245.75 (15.65) <sup>b</sup>	230.36 (15.17) <sup>ab</sup>	69.25 (8.32) <sup>ab</sup>	66.75 (8.17) <sup>a</sup>
HaNPV250LE/ha	385.63 (19.64) <sup>c</sup>	572.75 (23.93) <sup>d</sup>	138.38 (11.76) <sup>c</sup>	62.50 (7.90) <sup>a</sup>
Bird perches one/plot	331.50 (18.20) <sup>bc</sup>	302.75 (17.39) <sup>bc</sup>	111.38 (10.55) <sup>bc</sup>	69.50 (8.33) <sup>a</sup>
Endosulfan 0.07%	136.50 (11.68) <sup>a</sup>	115.75 (10.76) <sup>a</sup>	40.75 (6.38) <sup>a</sup>	48.25 (6.94) <sup>a</sup>
IPM	244.63 (15.65) <sup>b</sup>	231.88 (15.22) <sup>ab</sup>	104.63 (10.23) <sup>bc</sup>	75.75 (8.70) <sup>a</sup>
Control	380.00 (19.47) <sup>c</sup>	513.00 (22.61) <sup>cd</sup>	140.00 (11.80) <sup>c</sup>	73.25 (8.56) <sup>a</sup>
S.Ed.	1.725	2.643	1.063	0.909
CD	3.678	5.634	2.266	1.912

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant



Fig. 8: Effect of the treatments on soil inhabiting natural enemies during *rabi* 1998-99



significant from HaNPV and bird perches which showed no effect and were found on par with control (140.0/trap).

### **Preharvest stage**

At preharvest stage there was no significant difference in number of natural enemies among all the treatments.

#### **4.2.2 Effect of the Treatments on Natural Enemies Present on Chickpea Crop Canopy During *rabi* 1998-99**

To assess the effect of different IPM components on aerial natural enemies, a De Vac trap was used and the data on the natural enemies observed in the trap collection are presented in Table.18 (Figure.9). Natural enemies belonging to the order Hymenoptera such as braconids, chalcidids, ichneumonids, trichogrammatids, ants and others such as spiders, small crickets, tachinids etc., were considered for observations. During *rabi* 1998-99 at 22 days after sowing (one day after treatment) the first sampling of aerial natural enemies was done with De Vac. The results suggested a maximum reduction in natural enemies present on foliage in plots treated with endosulfan, neem and IPM (39.5, 50.0, 51.0 per two rows respectively). There was no significant reduction of the number of natural enemies present in plots treated with HaNPV (69.7/two rows) and bird perches (84.7/ two rows) which were found on par with control (87.1/two rows).

At 54days after sowing i.e., two days after 3<sup>rd</sup> spraying, the second sampling of aerial natural enemies was done. The results suggested a significant reduction in the number of natural enemies present on foliage in the plots treated with endosulfan and IPM treatment which received endosulfan as third spray (9.8, 11.4 per two rows, respectively). No

Table 18 : Effect of the treatments on natural enemies present on crop canopy during *rabi* 1998-99

Treatment	Number of natural enemies/two rows (36m)	
	22DAS(1DAT)	54DAS(2DAT)
Neem 0.006% (AZA 3%)	50.00 (7.06) <sup>ab</sup>	20.83 (4.56)
HaNPV 250LE/ha	69.73 (8.35) <sup>b</sup>	21.45 (4.63) <sup>b</sup>
Bird perches one/plot	84.69 (9.20) <sup>c</sup>	23.80 (4.88) <sup>b</sup>
Endosulfan 0.07%	39.45 (6.28) <sup>a</sup>	9.79 (3.13) <sup>a</sup>
IPM	51.00 (7.08) <sup>ab</sup>	11.39 (3.37) <sup>a</sup>
Control	87.06 (9.33) <sup>c</sup>	23.79 (4.86) <sup>b</sup>
Sed	0.630	0.341
CD	1.343	0.726

Mean of 4 replications

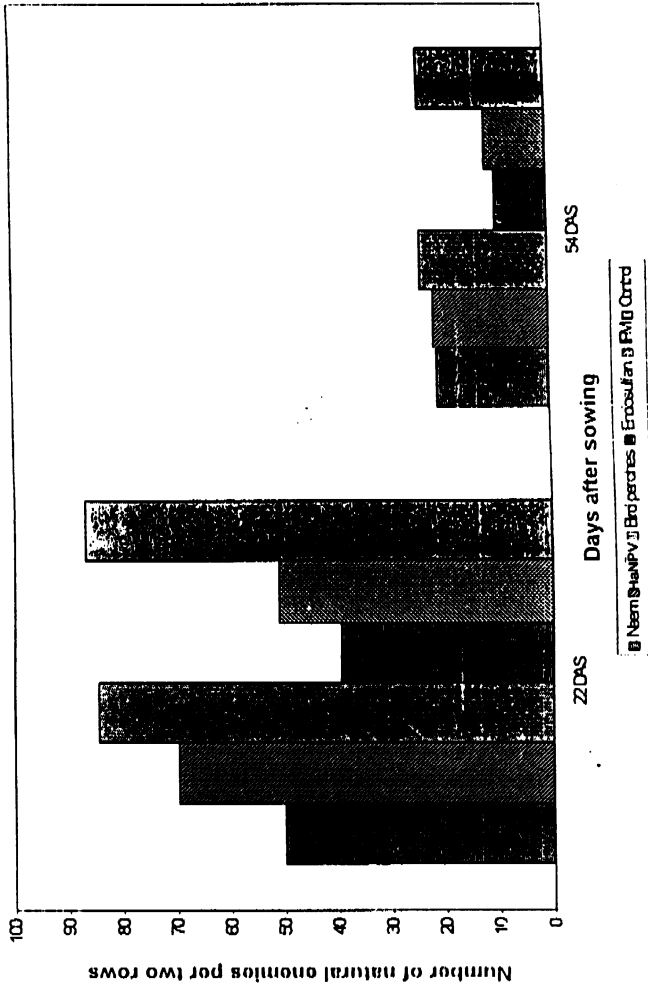
DAS = Days after sowing.

DAT = Days after treatment.

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

Fig. 9 : Effect of the treatments on natural enemies present on crop canopy during *rabi* 1998-99



significant reduction of natural enemies was observed in the plots treated with neem, HaNPV and bird perches compared to control (20.8, 21.5, 23.8, 23.8 per two rows, respectively).

#### **4.2.3 Effect of the Treatments on Soil Inhabiting Natural Enemies During *rabi* 1999-2000**

An experiment was conducted during *rabi* 1999-2000 in order to assess the effect of different IPM components individually and in combination on soil inhabiting natural enemies present during the crop growth. Observations on natural enemies in different treatments were recorded with the help of pitfall traps at ten days interval and the mean number of natural enemies per treatment at different crop stages were calculated. Sprayings were given at fifteen days interval during the period of crop growth (Table.19 & Figure.10).

##### **Vegetative stage**

During vegetative stage the plots treated with endosulfan recorded significantly less number of natural enemies present on the ground (79.0/trap). The remaining treatments Viz., HaNPV (148.6/trap), neem (153.3/trap), bird perches (158.5/trap) and IPM (217/trap) caused negligible reduction in number of natural enemies compared to control (224.7/trap) but the differences were not significant.

##### **Flowering stage**

During flowering stage also the highest reduction of natural enemies was observed in the plots treated with endosulfan (208.3/trap). There was no significant difference among the plots treated with HaNPV, neem, bird perches and IPM which received HaNPV as second spray (236.5, 238.8, 257.5, 294.0 per trap, respectively) being on par and recorded significantly less number of natural enemies compared to control (397.9/trap).

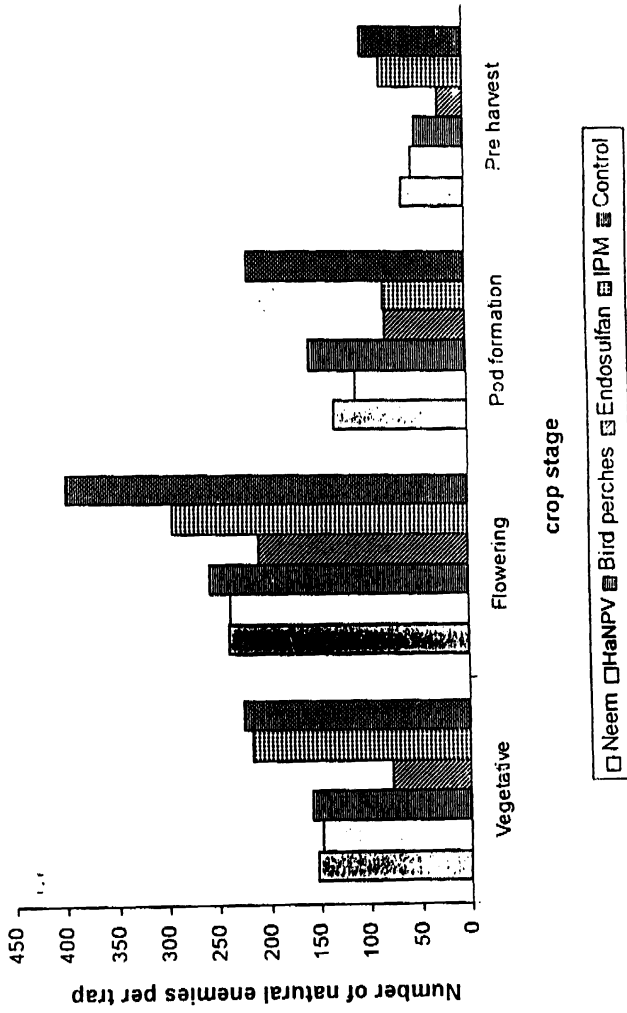
Table 19: **Effect of the treatments on soil inhabiting natural enemies in chickpea during *rabi* 1999-2000**

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of natural enemies/trap)			
Neem 1750 ml/ha (Nivaar 1500 ppm)	153.25 (12.38) <sup>b</sup>	238.75 (15.45) <sup>ab</sup>	133.50 (11.55) <sup>b</sup>	62.55 (8.91) <sup>b</sup>
HaNPV250LE/ha	148.60 (12.19) <sup>b</sup>	236.50 (15.38) <sup>ab</sup>	111.43 (10.55) <sup>ab</sup>	53.45 (7.31) <sup>ab</sup>
Bird perches one/plot	158.50 (12.59) <sup>b</sup>	257.52 (16.04) <sup>ab</sup>	157.25 (12.54) <sup>bc</sup>	49.55 (7.04) <sup>ab</sup>
Endosulfan 0.07%	79.03 (8.89) <sup>a</sup>	208.29 (14.43) <sup>a</sup>	79.86 (8.93) <sup>a</sup>	25.00 (5.06) <sup>a</sup>
IPM	216.95 (14.73) <sup>b</sup>	294.00 (17.14) <sup>b</sup>	81.78 (9.04) <sup>a</sup>	83.17 (9.12) <sup>b</sup>
Control	224.70 (14.99) <sup>b</sup>	397.88 (19.94) <sup>c</sup>	216.58 (14.71) <sup>c</sup>	102.25 (10.11) <sup>b</sup>
S.Ed.	1.397	0.973	1.068	1.552
CD	2.978	2.073	2.246	3.263

(Figures in parenthesis are square root transformed values)

\*Values followed by same letters in each column are statistically not significant

Fig. 10 : Effect of the treatments on soil inhabiting natural enemies during *rabi* 1999-2000



### **Pod formation stage**

At pod formation stage control (216.6/trap) recorded the highest level of soil natural enemy fauna. But endosulfan spray and IPM that received endosulfan as third spray highly reduced the natural enemy fauna (79.9, 81.9/trap, respectively). HaNPV (111.4/trap) and neem (133.5/trap) were on par and stood next in reducing natural enemies that were present on ground. Bird perches (157.3/trap) caused no significant reduction of ground dwelling natural enemies compared to control (216.6/trap).

### **Preharvest stage**

During preharvest stage endosulfan spray was again found toxic to the ground natural enemies (25.0/trap). All the remaining treatments did not show any significant effect compared to control on soil dwelling natural enemies.

#### **4.2.4 Mean effect of the treatments on soil inhabiting natural enemies**

The mean data regarding the effect of different IPM components on soil dwelling natural enemies are presented in the Table 20 (Figure.11).

### **Vegetative stage**

The results revealed a significant reduction in number of natural enemies in plots treated with endosulfan (107.8/trap). The plots treated with neem stood next in reducing the natural enemies (199.5/trap). IPM (230.8), bird perches (245/trap) and HaNPV (267.1/trap) did not show any significant effect and were on par with control (302.4/trap).

### **Flowering stage**

At flowering stage also endosulfan was found highly toxic to ground dwelling natural enemies (162.0/trap). Neem (234.6/trap), IPM (262.9/trap)



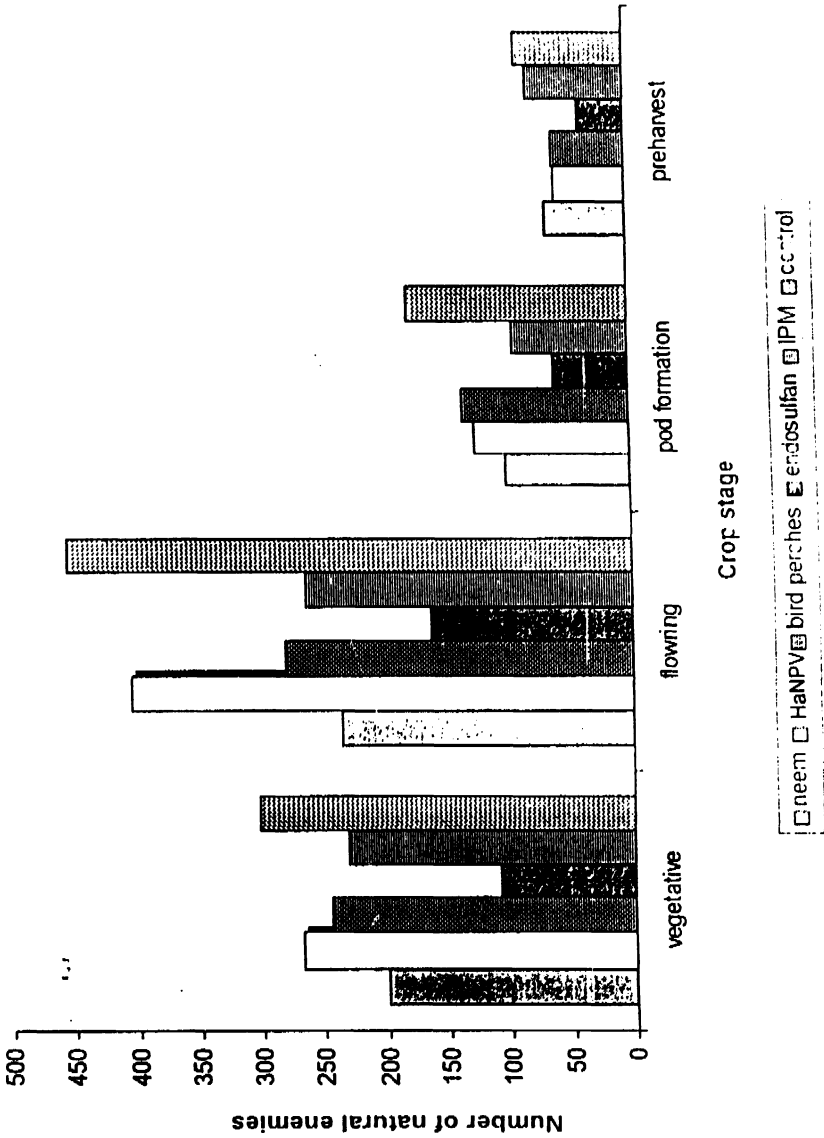
Table 20: Mean efficacy of the treatments on soil inhabiting natural enemies

Treatment/ Crop stage	Vegetative	Flowering	Pod formation	Preharvest
	(Mean number of natural enemies per trap)			
Neem	199.5 (14.12) <sup>b</sup>	234.58 (15.31) <sup>ab</sup>	101.38 (10.06) <sup>ab</sup>	64.65 (8.04) <sup>ab</sup>
HaNPV250LE/ha	267.12 (16.34) <sup>bc</sup>	404.63 (20.11) <sup>cd</sup>	124.91 (11.17) <sup>bc</sup>	57.98 (7.61) <sup>ab</sup>
Bird perches one/plot	245.0 (15.65) <sup>bc</sup>	280.14 (16.73) <sup>b</sup>	134.32 (11.58) <sup>bc</sup>	59.53 (7.71) <sup>ab</sup>
Endosulfan 0.07%	107.76 (10.38) <sup>n</sup>	162.02 (12.72) <sup>n</sup>	60.31 (7.76) <sup>n</sup>	36.63 (6.05) <sup>n</sup>
IPM	230.79 (15.19) <sup>bc</sup>	262.94 (16.21) <sup>abc</sup>	93.21 (9.65) <sup>ub</sup>	79.46 (8.91) <sup>b</sup>
Control	302.35 (17.38) <sup>c</sup>	455.44 (21.34) <sup>d</sup>	178.29 (13.35) <sup>c</sup>	87.75 (9.36) <sup>b</sup>
S.Ed.	1.268	1.904	1.119	1.012
CD	2.658	3.989	2.345	2.121

(Figures in parenthesis are square root transformed values)

Values followed by same letters in each column are statistically not significant

Fig 11: Mean effect of the treatments on soil dwelling natural enemies in chickpea.



and bird perches (280.1/trap) were on par and stood next in reducing ground dwelling natural enemies. HaNPV did not show any significant effect on natural enemies compared to control (455.4/trap).

### **Pod formation stage**

During this stage also endosulfan (60.3/trap) was found highly toxic to the ground inhabiting natural enemies however it was found on par with IPM (93.2/trap) and neem (101.4/trap). HaNPV (124.9/trap) and bird perches (134.3/trap) did not show any significant effect compared to control on ground dwelling natural enemies.

### **Preharvest stage**

During this stage also endosulfan (36.6/trap) was found toxic against the ground inhabiting natural enemies. All the remaining treatments did not cause any significant effect compared to control in reducing ground inhabiting natural enemies.

## **4.2.5 Effect of the Treatments on Natural Parasitism During *rabi***

**1998-99**

### **Larval parasitism**

The IPM treatments were compared for their role on the natural parasitism by *C.chlorideae* on the larvae of *H.armigera* and the results are presented in Table.21 (Plate.8). At 25 days after sowing i.e., 4 days after first treatment, maximum reduction in parasitisation (27%) by *C.chlorideae* was observed in endosulfan treatment. In the other treatments i.e neem and IPM which received neem, HaNPV and bird perches there was a non significant reduction in percentage parasitisation compared to control. At 58 DAS i.e., 6 days after third

Table 21 : Effect of the treatments on natural larval parasitisation by *Campoletis chloridae* Uchida during rabi 1998-99

Treatment	Parasitisation by <i>Campoletis chloridae</i> (%)	
	25DAS(4DAT)	58DAS(6DAT)
Neem 0.006 % (AZA 3%)	9.0 (17.41) <sup>ab</sup>	5.25 (13.50)
HaNPV250LE/ha	9.25 (17.61) <sup>ab</sup>	5.50 (13.50)
Bird perches one/plot	10.50 (18.89) <sup>b</sup>	7.00 (14.33)
Endosulfan 0.07%	8.00 (16.33) <sup>a</sup>	4.50 (12.01)
IPM	9.00 (17.41) <sup>ab</sup>	5.25 (13.03)
Control	11.00 (19.34) <sup>b</sup>	7.25 (15.53)
S.Ed.	1.04	1.28
CD	2.21	NS

DAS=Days after sowing

DAT=Days after treatment

(Figures in parenthesis are angular transformed values)

\*Values followed by same letters in each column are statistically not significant

treatment no significant difference between treatments in larval parasitisation was observed.

### **Pupal parasitisation**

Apart from larval parasitoid, a larval-pupal parasitoid *Carcelia illota* Curron (Tachinidae:Diptera) was also observed in control plots. However its incidence was very low i.e 2% at 58 DAS sampling.

## **4.2.6 Effect of the Treatments on Natural Parasitism During *rabi* 1999-2000**

### **Larval parasitism**

The results pertaining to larval parasitisation during *rabi* 1999-2000 are presented in Table.22. At 36 days after sowing i.e., four days after treatment the highest reduction in larval parasitisation by *C.chlorideae* was observed in endosulfan treatment (43%). Neem and IPM plots were on par and stood next with reduced larval parasitisation by *C.chlorideae* (38, 33%, respectively). In the remaining treatments also a reduction in parasitisation was observed but not at significant level.

At 68 days after sowing i.e., 6 days after 3<sup>rd</sup> spraying there was no significant difference among the treatments in parasitisation by *C.chlorideae* compared to control (9.50%).

### **Pupal parasitisation**

Larval-pupal parasitoid *C.illota* was also observed, however its incidence was very low i.e 4%.

## **4.2.6 Mean effect of the treatments on natural parasitism**

Cumulative data regarding the effect of different IPM components on natural parasitisation by *C.chlorideae* are presented in Table 23. The

Table 22: Effect of treatments on natural larval parasitisation by *Campoletis chloridae* Uchida during rabi 1999-2000

Treatment	Parasitisation by <i>Campoletis chloridae</i> (%)	
	36DAS(4DAT)	68DAS(6DAT)
Neem 1750 ml / ha (Nivaar 1500 ppm)	3.25 (10.34) <sup>ab</sup>	8.75 (17.14)
HaNPV250LE/ha	4.00 (11.46) <sup>abc</sup>	9.00 (17.43)
Bird perches one/plot	4.75 (12.53) <sup>bc</sup>	9.75 (18.16)
Endosulfan 0.07%	3.00 (9.92) <sup>a</sup>	8.50 (16.90)
IPM	3.50 (10.67) <sup>ab</sup>	8.50 (16.87)
Control	5.25 (13.03) <sup>c</sup>	9.50 (17.86)
S.Ed.	1.04	1.38
CD	2.21	NS

DAS = Days after sowing.

DAT = Days after treatment.

(Figures in parenthesis are arc sin transformed values)

\*Values followed by same letters are statistically not significant.

Table 23: Mean effect of the treatments on natural parasitisation by *Camponotus chlorideae* Uchida in chickpea.

Treatment	1 <sup>st</sup> sampling	2 <sup>nd</sup> sampling
Neem	6.13 (14.33) <sup>ab</sup>	7.00 (15.34)
HaNPV250LE/ha	6.63 (14.92) <sup>ab</sup>	7.25 (15.62)
Bird perches one/plot	7.63 (16.03) <sup>b</sup>	8.38 (16.82)
Endosulfan 0.07%	5.50 (13.56) <sup>a</sup>	6.50 (14.77)
IPM	6.25 (14.47) <sup>ab</sup>	6.88 (15.20)
Control	8.13 (16.56) <sup>b</sup>	8.38 (16.82)
S.Ed.	1.101	1.32
CD	2.340	NS

(Figures in parenthesis are arc sin transformed values)

\*Values followed by same letters in each column are statistically not significant

Table 24: Effect of the treatments in reducing pod damage by *H. armigera* in chickpea during *rabi* 1998-99.

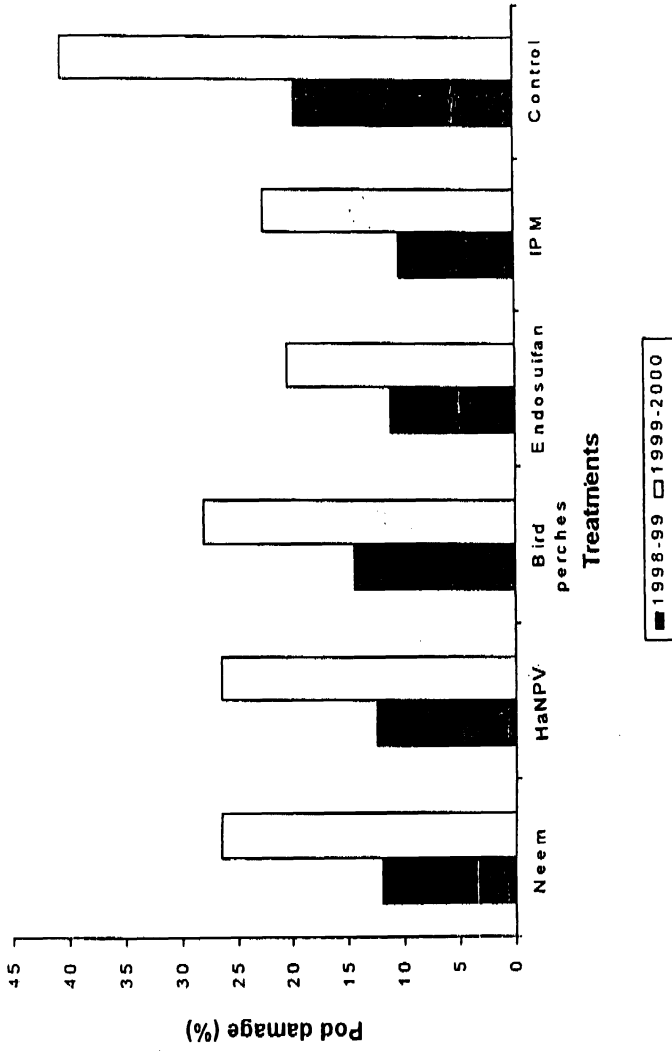
Treatment	Pod damage(%)	Per cent reduction over control
Neem 0.006% (AZA 3%)	11.98 (20.23) <sup>b</sup>	39.37
HaNPV250LE/ha	12.55 (20.72) <sup>b</sup>	36.49
Bird perches one/plot	14.45 (22.32) <sup>c</sup>	26.87
Endosulfan 0.07%	11.21 (19.56) <sup>ab</sup>	43.27
IPM	10.38 (18.77) <sup>a</sup>	47.47
Control	19.76 (26.41) <sup>d</sup>	-
S.Ed.	0.550	
CD	1.180	

(Figures in parenthesis are arc sin transformed values)

\*Values followed by same letters in each column are statistically not significant



Fig 12: Pod damage (%) due to *H. armigera* during both the years in chickpea in different treatments.



results revealed the highest reduction in natural parasitisation of larvae in plots treated with endosulfan (32%). All the remaining treatments did not show any significant effect compared to control in reducing larval parasitism by *C.chlorideae*. During second sampling there was no significant difference among the treatments in parasitisation by *C.chlorideae* compared to control (8.3%).

#### **4.3.1 Effect of the Treatments on the Pod Damage by *H. armigera* in Chickpea During *rabi* 1998-99**

A perusal of the data presented in Table 24 revealed that the maximum percentage of pod damage was observed in control (19.8%) (Plate.10 & Figure 12). Among the treatments IPM was found to be the best by registering the lowest percentage of pod damage (10.4%) with 47.5% reduction over control. Endosulfan treatment was also effective as IPM by registering 11.2% of pod damage with 43.3% reduction over control. Neem spray was found next best and was on par with HaNPV spray with 39.4 and 36.5 per cent reduction in pod damage over control, respectively. Bird perches treatment significantly reduced pod damage (14.5%) compared to control (26.9%).

#### **4.3.2 Effect of the Treatments on the Pod Damage by *H. armigera* in Chickpea During *rabi* 1999-2000**

The results (Table 25 & Figure 12) from a field trial indicated that endosulfan was found to be the best treatment by registering the lowest percentage of pod damage (20.5) the reduction being 49.7% over control but was on par with IPM treatment with 22.6 per cent pod damage (44.4% reduction over control). The treatments with neem and HaNPV were on par in reducing pod damage by registering 26.4 per cent pod damage. Bird perches

Table 25 : Effect of the treatments in reducing pod damage by *H.armigera* in chickpea during *rabi* 1999-2000

Treatment	Pod damage(%)	Per cent reduction over control
Neem 1750 ml/ha (Nivaar 1500 ppm)	26.44 (30.88) <sup>bc</sup>	35.08
HaNPV250LE/ha	26.39 (30.84) <sup>bc</sup>	35.21
Bird perches one/plot	28.08 (31.98) <sup>c</sup>	31.06
Endosulfan 0.07%	20.50 (26.63) <sup>a</sup>	49.67
IPM	22.60 (28.36) <sup>ab</sup>	44.39
Control	40.73 (39.64) <sup>d</sup>	-
S.Ed.	1.718	
CD	3.610	

(Figures in parenthesis are arc sin transformed values)

\*Values followed by same letters are statistically non significant

Table 26: Mean effect of the treatments in reducing pod damage by *H. armigera* in chickpea

Treatment control	Pod damage(%)	Per cent reduction over control
Neem	19.21 (25.99) <sup>bc</sup>	36.5
HaNPV250LE/ha	19.47 (26.18) <sup>bc</sup>	35.6
Bird perches one/plot	21.27 (27.46) <sup>c</sup>	29.7
Encosulfan 0.07%	15.86 (23.46) <sup>n</sup>	47.6
IPM	16.49 (23.95) <sup>ab</sup>	45.5
Control	30.25 (33.36) <sup>d</sup>	-
S.Ed.	1.137	
CD	2.39	

(Figures in parenthesis are arc sin transformed values)

\*Values followed by same letters are statistically not significant

were efficient in attracting many insectivorous birds, which can be viewed from the reduction in pod damage by 31.1% over control. The control plot recorded the highest pod damage of 40.7 per cent.

#### **4.3.3 Mean effect of the Treatments on the Pod Damage by *H. armigera* in Chickpea**

The mean data of the two years regarding pod damage are presented in Table 26. From the data it was clear that endosulfan was the best treatment by registering the lowest per cent of pod damage (15.9), the reduction being 47.6 per cent over control but was on par with IPM with 16.5 per cent pod damage (45.5 % reduction over control). The treatments neem, HaNPV and bird perches were on par in reducing pod damage with 19.2, 19.5 and 21.3 per cent pod damage, respectively. The control plot recorded the highest pod damage of 30.3%.

#### **4.4.1 Effect of the Treatments on Chickpea Yield During *rabi* 1998-99**

To assess the efficacy of different IPM components on the grain yield of chickpea, studies were conducted and the results are elucidated in Table.27 & Figure.13. The results revealed that IPM was significantly the best treatment by recording the highest yield, 1167 kg/ha, which was 57.3 per cent higher over control (741.8 kg/ha), followed by endosulfan spray 1054 kg/ha which recorded 42 per cent yield increase over control. HaNPV (963.8 kg/ha) and neem (961.8 kg/ha) stood next, being on par and significantly effective by recording 29.7 and 29.9 per cent yield increase over control, respectively. Even though the plots with bird perches recorded significantly less yield (858 kg/ha) than the remaining treatments, it was also found to be significantly effective by registering 15.7 per cent yield increase over control.

Table 27 : Effect of the treatments on the grain yield of chickpea during *rabi* 1998-99

Treatment	Grain yield (kg/ha)	Per cent increase over control
Neem 0.006% (AZA 3%)	961.8 <sup>c</sup>	29.7
HaNPV250LE/ha	963.9 <sup>c</sup>	29.9
Bird perches one/plot	858 <sup>d</sup>	15.7
Endosulfan 0.07%	1054 <sup>b</sup>	42
IPM	1167 <sup>a</sup>	57.3
Control	741.8 <sup>e</sup>	-
S.Ed.	34.15	
CD	72.77	

Values followed by same letters are statistically not significant.

Fig 13: Effect of the treatments on yield during both the years in chickpea.

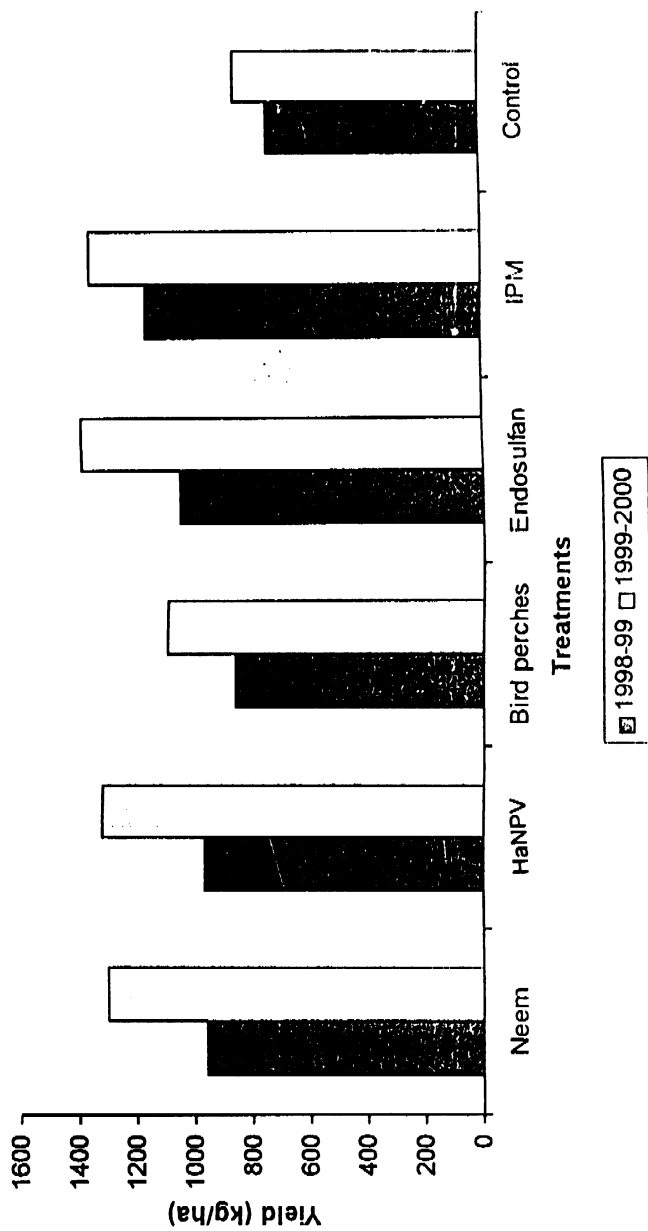


Table 28 : Effect of the treatments on the grain yield of chickpea during *rabi* 1999-2000

Treatment	Grain yield (kg/ha)	Per cent increase over control
Neem 1750 ml/ha (Nivaar 1500 ppm)	1298 <sup>b</sup>	51.9
HaNPV250LE/ha	1317 <sup>b</sup>	54.2
Bird perches one/plot	1096 <sup>c</sup>	28.3
Endosulfan 0.07%	1392 <sup>"</sup>	63.1
IPM	1361 <sup>ab</sup>	59.4
Control	854 <sup>d</sup>	-
S.Ed.	34.5	
CD	72.4	

Values followed by same letters are statistically not significant.



#### **4.4.2 Effect of the Treatments on Chickpea Yield During *rabi* 1999-2000**

From the results presented in Table.28 & Figure.13 endosulfan was adjudged as the superior among the treatments by recording the highest yield of 1392 kg/ha which was 63 per cent increase over control. Due to integration of the pest management strategies, IPM was on par with endosulfan spray with 1361.7 kg/ha an increase of 59.4 per cent over control. The treatment HaNPV (1317 kg/ha) and neem (1298 kg/ha) were also found significantly effective in increasing the yield upto 54 and 52 per cent increase over control, respectively. Plots with bird perches also recorded 28 per cent increase in the grain yield over control mainly because of immense bird activity at ICRISAT location.

#### **4.4.3 Mean Effect of the Treatments on Chickpea Yield**

Mean data of the two years are presented in Table 29. The results revealed that IPM was found to be the best treatment, by recording the highest grain yield 1264.4 kg/ha, which was 58.5 per cent increase over control (797.9 kg/ha) but it was on par with plots treated with endosulfan spray (1223 kg/ha) with 53.3 per cent increase over control. HaNPV (1140.4 kg/ha) and neem (1129.9 kg/ha) were on par and recorded significantly higher yields with 42.9 and 41.6 per cent increase over control, respectively. Even though bird perches (977 kg/ha) was inferior than the other treatments it was also found to be significantly effective by registering 22.5 per cent increase over control.

#### **4.5.1 The economics of the Treatments During *rabi* 1998-99**

The cost-benefit ratio's which were worked out for different treatments (Table.30) showed a higher cost benefit ratio (1:3.32) with bird perches plot but the overall yield increase over control was very less. IPM due to the integration of different management strategies showed the highest cost

Table 29: Mean effect of the treatments on the grain yield of chickpea.

Treatment	Grain yield (kg/ha)	Per cent increase over control
Neem	1129.9 <sup>b</sup>	41.6
HaNPV250LE/ha	1140.4 <sup>b</sup>	42.9
Bird perches one/plot	977 <sup>c</sup>	22.5
Endosulfan 0.07%	1223 <sup>a</sup>	53.3
IPM	1264.4 <sup>a</sup>	58.5
Control	797.9 <sup>d</sup>	-
S.Ed.	34.26	
CD	72.02	

\*Values followed by same letters are statistically not significant

Table 30: Cost Benefit ratio of IPM components in chickpea during *rabi* 1998-99

Treatment	Grain Yield (kg/ha)		Gross income (Rs.)	Insecticidal & application cost (Rs.)	Net income (Rs.)	C:B (Cost Benefit ratio)
	Gross	Additional yield over control				
Neem 0.006% (AZA 3%)	961.8	220.0	9,618	1,750	7,868	1:1.26
HaNPV 250LE/ha	963.9	222.0	9,638	2,000	7,638	1:1.10
Bird perches one/plot	858.0	116.2	8,580	350	8,230	1:3.32
Endosulfan 0.07%	1054.1	312.3	10,541	1,725	8,816	1:1.81
IPM	1167.0	425.2	11,670	1,845	9,825	1:2.30
Control	741.8	-	7,418	-	7,418	-

Cost of each spray/ha

Neem = Rs 350/-

HaNPV = Rs 400/-

Bird perches = Rs 350/ha

Endosulfan = Rs 345/-

Cost of chickpea = Rs10.0 / kg

Table 31: Cost Benefit ratio of IPM components in chickpea during *rabi* 1999-2000

Treatment	Grain Yield (kg/ha)		Gross income (Rs.)	Insecticidal & application cost (Rs.)	Net income (Rs.)	C:B (Cost Benefit ratio)
	Gross	Additional yield over control				
Neem 1750 ml/ha (Nivaar 1500 ppm)	1298.0	444.0	19,470	2,297	17,173	1:2.90
HaNPV 250LE/ha	1317.1	463.1	19,756	2,645	17,111	1:2.63
Bird perches one/plot	1096.0	242.0	16,440	350	16,090	1:10.37
Endosulfan 0.07%	1392.0	534.0	20,894	2,159	18,735	1:3.71
IPM	1361.7	507.0	20,426	2,025	17,990	1:3.76
Control	854.0	-	12,810	-	12,810	-

Cost of each spray/ha

Neem = Rs 459/-

HaNPV = Rs 529/-

Bird perches = Rs 350/ha

Endosulfan = Rs 432/-

Cost of chickpea = Rs15.0/kg

Table 32: Cost Benefit ratio of IPM components in chickpea (cumulative of two years)

Treatment	Grain Yield (kg/ha)		Gross income (Rs.)	Insecticidal & application cost (Rs.)	Net income (Rs.)	C:B (Cost Benefit ratio)
	Gross	Additional yield over control				
Neem	1129.9	332.0	14,544	2,023.5	12,520.5	1:2.05
HaNPV 250LE/ha	1140.45	342.55	14,697	2,322.5	12,374.5	1:1.84
Bird perches one/plot	977.00	179.1	12,510	350.0	12,160.0	1:6.40
Endosulfan 0.07%	1223.05	425.15	15,717.5	1,942.0	13,775.5	1:2.74
IPM	1264.35	466.45	16,048	1,935.0	13,907.5	1:3.01
Control	797.9	-	10,114	-	10,114.0	-

Cost of each spray/ha

Neem = Rs 405/-

HaNPV = Rs 465/-

Bird perches = Rs 350/ha

Endosulfan = Rs 388/-

Cost of chickpea = Rs12.5/kg

benefit ratio (1:2.30) among the remaining treatments with considerable increase in yield over control. Endosulfan used in the experiment was comparatively cheaper chemical and proved to be cost effective with a cost benefit ratio of 1:1.81. Neem and HaNPV were next best treatments with 1:1.26 and 1:1.10 C:B ratio's, respectively.

#### 4.5.2 The Economics of the Treatments During *rabi* 1999-2000

During *rabi* 1999-2000 the results (Table.31) revealed that bird perches treatment was most economical with 1:10.37 cost-benefit ratio. However the overall yield and the yield increase over control was much less. Among the remaining treatments IPM was the most economical treatment which registered the highest cost-benefit ratio of 1:3.76 followed by endosulfan treatment (1:3.71). Neem spray stood next in the order of efficacy with the cost-benefit ratio of 1:2.90 and the lowest cost-benefit ratio was obtained with HaNPV spray (1:2.60).

#### 4.5.3 The Economics of the Treatments (mean of two years)

The cost-benefit ratios were worked out to know the economics of different IPM components individually and in combination. The results (Table 31) revealed that although bird perches gave the highest cost-benefit ratio (1:6.40) the overall yield and the yield increase over control was much less. Among the remaining treatments highest cost-benefit ratio (1:3.01) was obtained by integration of all IPM components. Endosulfan proved to be the effective and cheaper chemical with 1:2.74 cost-benefit ratio. Neem spray with 1:2.05 ratio proved economical compared to HaNPV (1:1.84).

#### 4.6 Residues of Endosulfan in Chickpea Seed and Husk

The presence of residues were tested only in the sample of *rabi* season 1999-2000. The results (Table 33) suggested presence of residues

Table 33 : Endosulfan residues in chickpea seed and husk

Sample	Alpha Endosulfan (mg/kg)	Beta Endosulfan (mg/kg)	Endosulfan sulphate (mg/kg)	Total endosulfan (mg/kg)
Endosulfan treatment				
Seed	0.322	0.461	0.022	0.805
Husk	0.460	0.475	0.415	1.350
IPM treatment				
Seed	BDL	BDL	BDL	BDL
Husk	BDL	BDL	BDL	BDL
MRL				2.00

BDL-Below detectable limit

MRL-Maximum residual limit acceptable as per FAO standards.

in the samples collected from endosulfan treatment in seeds as well as in husk also. The seeds of chemical plot contained 0.81mg/kg endosulfan residues where as husk contained 1.35mg/kg endosulfan residues but both are lower than the maximum residual limit prescribed by FAO (2mg/kg). The samples collected from IPM plot showed residues below detectable limit both in seed and husk.

## 4.7 LABORATORY STUDIES

### 4.7.1 Effect of Neem as Oviposition Deterrent Against *H.armigera* Adults

To determine the oviposition deterrent effect of neem 30 days old chickpea plants in pots were taken and half of them were sprayed with neem and the remaining half with water. Fifteen pairs of *H.armigera* adults (12 hrs old) were released, and the egg number laid on chickpea plants was counted till the death of adults. The results (Table 34) showed significantly lower number of eggs on neem treated plants i.e., 111.60 compared to 287.80 eggs in control, which clearly revealed the oviposition deterrent effect of neem on chickpea against *H.armigera* adults.

### 4.7.2 Effect of neem as Antifeedant Against *H.armigera* In Choice Test (Table 35)

Small size larvae (first & second instars) were observed for their orientation towards neem treated and untreated chickpea leaves. The data showed 46% of larvae settled on neem treated leaves and 47% on untreated control, suggesting no significant difference between the treatments.

In medium larvae (third & fourth instars) 36% settled on neem treated leaves and pods and 54% on untreated chickpea leaves and pods. Where as 22% of large larvae (fifth & sixth instars) were settled on neem treated and 78% on untreated chickpea leaves and pods.



Table 34 : Effect of neem on *H.armigera* oviposition

Treatment	Mean number of eggs laid/pot	S.Em.
Neem 0.006%	111.60	6.63
Control(water spray)	287.80	4.92

Means are significantly different by the two sample t-test.

Based on the above experiment it was concluded that with increase in larval age, their differentiation between neem treated and untreated leaves increased.

#### **In no choice test**

Different age groups of larvae were observed for their preference towards neem treated chickpea leaves and pods in no choice situations. When larvae were given food mixed with neem under no choice situation, the initial behavior was evident in older larvae by moving around the food perhaps in search of better option. Since there was no option ultimately the larvae settled on the neem impregnated diet. It was clear from the study that the response of the larvae to neem increases as the larvae advance in age. 40% of the large larvae (fifth & sixth instar), 20% of the medium (third & fourth instars) and none of the small size larval group (first & second instars) showed initial avoidance of neem.

#### **4.7.3 Effect of neem on different age groups of *H.armigera***

Chickpea leaves sprayed with neem 0.006% were given to larvae of different age groups i.e. small (first & second instars), medium (third & fourth instars) and large (fifth & sixth instars) to assess the effect and the data are presented in Table 36.

#### **Larval mortality**

Neem treatment gave 47.9% larval mortality of small larvae as against 9.1% in control. While in medium larval group only 15.8% larval mortality was observed in neem treatment as against 5.3% mortality in control. Where as large larvae experienced no mortality.

Table 35 : Neem as antifeedant in choice test against different age groups of *H.armigera*

**I & II instars**

Treatment	Mean number of larvae Settled	S.Em.
Neem	4.6	0.617
Control	4.7	0.539

Means are statistically not significant by two sample t-test.

**III & IV instars**

Treatment	Mean number of larvae Settled	S.Em.
Neem	3.6	0.600
Control	5.4	0.539

Means are statistically significant by two sample t-test.

**V & VI instars**

Treatment	Mean number of larvae Settled	S.Em.
Neem	2.2	0.326
Control	7.8	0.327

Means are statistically significant by two sample t-test.

**Larval duration**

There was significant increase of mean larval duration in all the age groups when they received neem treatment. Small larval group took 14.9 days when they provided with neem treated food as against 12.9 days in control to complete larval stage. Medium size larvae took 9.4 days as against 8.3 days in control, where as large size larvae took 5.1 days with neem as against 3.8 days in control treatment to complete the larval stage.

**Pupal weight**

Small (285.6 mg) and medium (310 mg) age groups showed significant decrease in pupal weight compared to control (372.4 , 370.3 mg resp.) when they were provided neem treated leaves as food compared to control, where as large size larvae (339.0 mg) showed non significant difference in pupal weight compared to control (357.7mg).

**Pupal period**

The small size larval group showed significant increase in pupal period (13.9 days) compared to control (10.3 days). Medium size larval group also showed significant increase in pupal period (12.0 days) compared to control (10.1 days) when they received neem treated leaves as food. But large size larval group showed non significant increase in pupal period (11.53 days) compared to control (11.48 days).

**Oviposition period**

There was a significant decrease in oviposition period of adults emerged from all the three age groups compared to control when fed with neem treated leaves during the larval stage. In the adults obtained from small larval group fed with neem treated leaves the oviposition period was 3.7 days as against 6.5 days in control, where as in medium group 4.5

Table 36 : Effect of neem on different stages of *H.armigera*

	Neem	Control	Significance
Larval mortality(%)			
I&II	47.89	9.06	sig
III&IV	15.75	5.29	sig
V&VI	-	-	-
Larval duration(Days)			
I&II	14.85	12.9	sig
III&IV	9.43	8.3	sig
V&VI	5.12	3.84	sig
Pupal weight (mg)			
I&II	285.6	372.4	sig
III&IV	310.1	370.3	sig
V&VI	339	357.7	NS
Pupal period(Days)			
I&II	13.88	10.25	sig
III&IV	12.02	10.13	sig
V&VI	11.53	11.48	NS
Oviposition period(Days)			
I&II	3.72	6.47	sig
III&IV	4.51	6.93	sig
V&VI	4.7	6.03	sig
Fecundity(Number)			
I&II	838.7	1697	sig
III&IV	937.5	1779	sig
V&VI	1049.7	1679	sig
Egg hatchability (%)			
I&II	89.75	91.02	NS
III&IV	89.98	87.29	NS
V&VI	93.14	94.5	NS

days as against 6.9 days in control. While in large size larval group it was 4.7 days compared to 6.0 days in control.

### **Fecundity**

Significant decrease in number of eggs laid by the resultant females of all the age groups of larvae fed with neem treated food compared to control was observed. In small larvae group 838.7 eggs per moth were recorded as against 1697 eggs per moth in control. In medium larvae group 937.5 eggs per moth compared to 1779 eggs per moth in control. Where as in large larvae group 1049.7 eggs per moth compared to 1679 eggs per moth in control was observed.

### **Egg hatching**

No significant difference was observed in egg hatching between neem treated and control in all the three age groups.

#### **4.7.4 Efficacy of Robin Blue in Increasing the Persistence of HaNPV on Chickpea Foliage**

To assess the efficacy of robin blue (1%) in increasing the persistence of HaNPV as UV rays protectant, an experiment was conducted by using 3<sup>rd</sup> instar larvae of *H. armigera* and the results are presented in Table 37 & Figure 14.

The data revealed that HaNPV and HaNPV+ robin blue (1%) treatments were on par with 75% and 76.2% mortality, respectively when fed with the leaves immediately after treatment, the corresponding mortality in control was 4.8%. When the treated leaves were fed one day after spray with HaNPV+ robin blue (1%) recorded significantly higher mortality i.e 51.2% as against 34.5% with HaNPV alone. Control registered no mortality. When

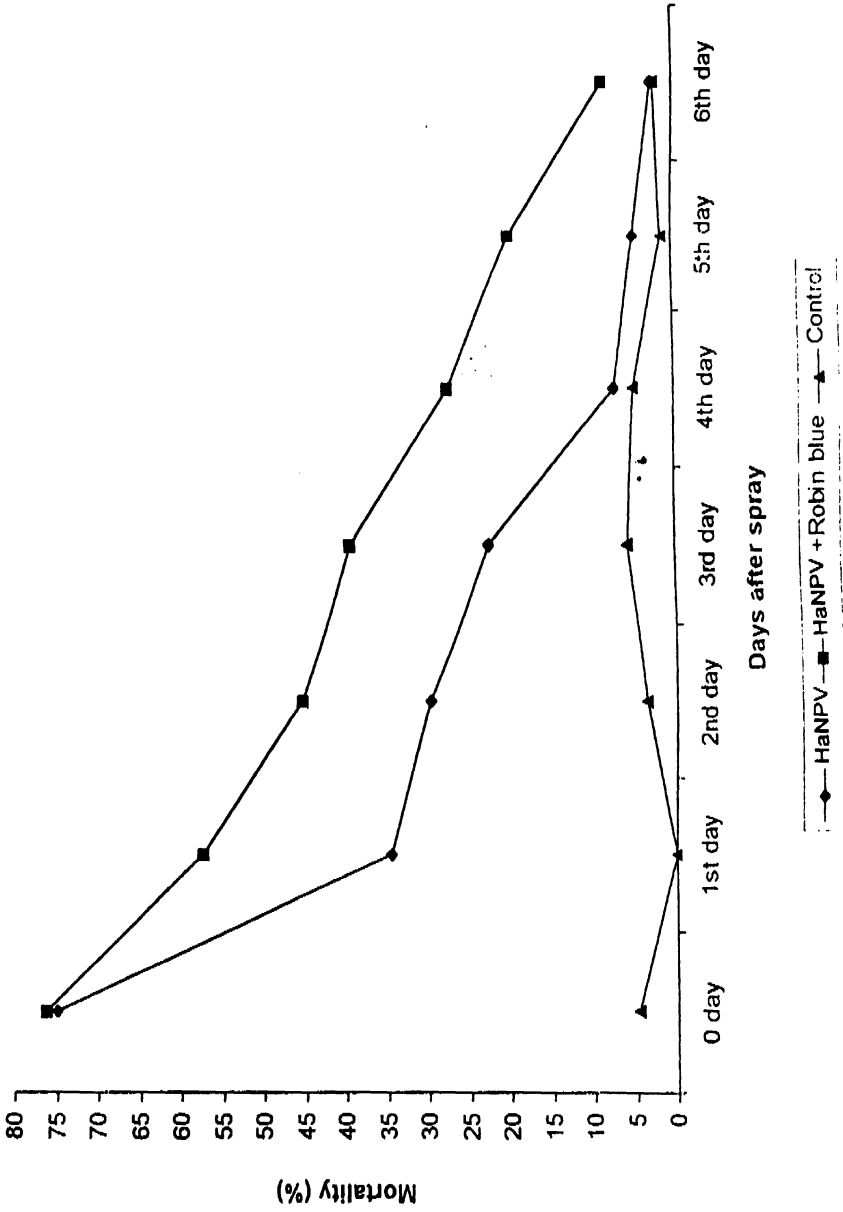
Table 37: Persistence of HaNPV on chickpea foliage with / without Robin blue against 3rd instar larvae of *H. armigera*

Days after Treatment	HaNPV alone	HaNPV+ Robin blue 1%	Control	S.Ed.	CD
(Larval mortality (%))					
0	75 (60.5) <sup>a</sup>	76.19 (61.7) <sup>a</sup>	4.76 (10.0) <sup>b</sup>	2.43	5.29
1 <sup>st</sup>	34.52 (35.9) <sup>b</sup>	57.19 (45.7) <sup>a</sup>	0 (0.2238) <sup>c</sup>	1.26	2.7
2 <sup>nd</sup>	29.76 (33.0) <sup>b</sup>	45.24 (42.5) <sup>a</sup>	3.57 (5.8) <sup>c</sup>	1.77	3.85
3 <sup>rd</sup>	22.62 (28.3) <sup>b</sup>	39.29 (38.66) <sup>a</sup>	5.67 (13.8) <sup>c</sup>	1.15	2.5
4 <sup>th</sup>	7.14 (13.0) <sup>b</sup>	27.52 (35.9) <sup>a</sup>	4.98 (12.9) <sup>b</sup>	1.57	3.42
5 <sup>th</sup>	4.76 (8.2) <sup>b</sup>	19.76 (32.9) <sup>a</sup>	1.19 (4.4) <sup>b</sup>	2.7	4.5
6 <sup>th</sup>	2.58 (4.8) <sup>b</sup>	8.53 (14.1) <sup>a</sup>	2.38 (4.8) <sup>b</sup>	2.14	4.67

(Figures in paranthesis are arc sin transformed values)

\*Values followed by same letters in each row are statistically not significant

Fig 14: Efficacy of HaNPV with / without Robin blue on chickpea foliage against 3rd instar larvae of *H. armigera*





the larvae were fed with the treated leaves after 48 hours once again HaNPV+ robin blue (1%) gave significantly high mortality (45.2%) compared to HaNPV (29.8%) and control 3.6%. Similarly HaNPV+ robin blue (1%) treatment showed significantly high rate of mortality (39.3%) compared to HaNPV (22.6%) and control (5.7%) when larvae were fed with the leaves 3 days after treatment. When the larvae were fed with the leaves 4 days after treatment again HaNPV+robin blue (1%) recorded significantly high mortality (27.5%) while HaNPV treatment (7.1%) was not significantly different from control (5%). Even 5 days after treatment HaNPV+ robin blue (1%) treated leaves when fed gave 19.8% mortality of the larvae and thus proved to be a good UV protectant by retaining HaNPV persistence, while HaNPV (4.8%) showed non significant mortality compared to control (1.2%). Robin blue continued to show UV protectant ability by causing 8.5% mortality when combined with HaNPV compared to 2.6% with HNPV alone and 2.4% on control when the larvae were fed with the treated leaves after six days.

#### 4.7.5 Effect of HaNPV on Three Different Age Groups of *H.armigera*

Effect of HaNPV on different age groups of *H.armigera* i.e., small (first & second instars), medium (third & fourth instars) and large (fifth & sixth instars) larvae in terms of larval mortality, pupal abnormality and death, pupal weight and fecundity were studied and the results are presented in Table 37.

#### Larval mortality

HaNPV treatment @  $6 \times 10^9$  POB / l on small larvae (first & second instars) gave complete mortality as against 2.7% mortality in control. Medium larvae (third & fourth instars) registered 76.8% mortality as against 3.5% mortality in control. Large larvae (fifth & sixth instars) recorded 59.8% mortality as against no mortality in control.

Table 38: Effect of HaNPV on different stages of *H. armigera*

	HaNPV	Control	Significance
Larval mortality(%)			
I&II	100	2.68	Sig
III&IV	76.75	3.5	Sig
V&VI	59.80	-	Sig
Pupal abnormality(%)			
I&II	-	-	
III&IV	97.95	-	Sig
V&VI	86.90	-	Sig
Pupal weight (mg)			
I&II	-	-	
III&IV	290.47	375.67	Sig
V&VI	349.43	357.93	NS
Fecundity (number)			
I&II	-	-	
III&IV	397	1079	Sig
V&VI	689	865	Sig

### **Pupal abnormality and death**

Pupal abnormality and death was not recorded in small size larvae as there was 100% mortality at larval stage itself. Medium larvae group recorded 98.0 % pupal abnormality and death where as large larvae group recorded 86.9% pupal abnormality and death.

### **Pupal weight**

Small larvae did not reach pupal stage but in medium group there was significant reduction in pupal weight (290.5 mg) of the resultant pupae from the treated larvae as against control (375.7 mg). Where as in large larval group there was non significant difference between HaNPV treated and normal pupal weight (349.4 & 357.9 mg, respectively).

### **Fecundity**

In the adults developed from the HaNPV treated medium larval group there was a significant reduction in number of eggs (397 per female) due to early death of male and female moths compared to control (1079 eggs per female). Similar trend was observed in the adults developed from the HaNPV treated large larval group with significantly lower number of eggs per female (689) compared to control (865 eggs per female).

#### **4.7.6 Effect of HaNPV treatment at fifth instar larval stage on fecundity of *H.armigera***

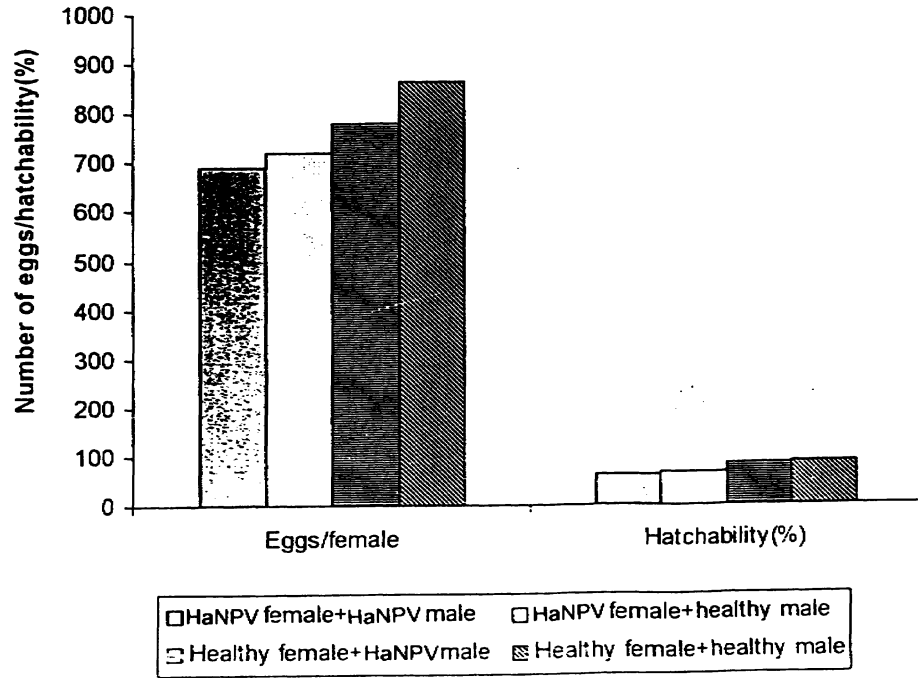
A significant reduction in number of eggs laid per female was observed in all the treatments that included either male or female or both that emerged from HaNPV fed larvae at fifth instar stage compared to control (Table 39 & Figure.15). There was only 79.6% ovipositional potential realised in treated larvae in comparison with control where both male and female moths were from HaNPV infected larval population, where

**Table 39: Effect of HaNPV treatment on fecundity and egg hatchability of *H. armigera* when received at 5th instar stage.**

Treatment	Number of eggs/ female	Reduction against control(%)	Hatchability(%)	Reduction against control(%)
HaNPVfemale + HaNPVmale	689 (25.98) <sup>a</sup>	20.40	62.62 (52.80) <sup>a</sup>	30.47
HaNPVfemale + healthy male	718 (26.59) <sup>a</sup>	17	65.20 (54.00) <sup>a</sup>	27.60
Healthy female + HaNPVmale	780 (27.88) <sup>ab</sup>	9.83	83.73 (67.50) <sup>b</sup>	7.03
Healthy female + healthy male	865 (29.39) <sup>b</sup>	-	90.06 (73.90) <sup>c</sup>	-
S.Ed.	1.202		2.87	
CD	2.619		6.25	

\*Values followed by same letters in each column are statistically not significant

Fig 15: Effect of HaNPV treatment on fecundity and egg hatchability of *H. armigera* when received at 5th instar stage.



as 83% of egg laying was observed in treatment where female from HaNPV infected population and male from normal population were allowed to mate. 90.2% egg laying compared to control was observed in the treatment that included female from normal population and male from HaNPV infected population. Thus both male and female adults that emerged from HaNPV fed larvae showed profound effect on the total fecundity.

#### **4.7.7 Effect of HaNPV Treatment at Fifth Instar Larval Stage on Hatching of eggs of *H.armigera* (Table 39 & Figure 15)**

When the fifth instar larvae of *H.armigera* were treated with HaNPV @  $6 \times 10^9$  POB/l, a significant reduction in hatching of the eggs laid by moths of resultant population was observed compared to control. When both male and female adults were collected from HaNPV treated population at fifth instar larval stage only 62.6% egg hatchability was observed i.e 30.5% reduction compared to control. Eggs from female collected from HaNPV treated population at fifth instar larval stage and male collected from normal population had 65.2% hatching i.e 27.60% reduction compared to control. When male was collected from HaNPV treated population at fifth instar larval stage and female from normal population the resultant eggs recorded 83.7% hatching i.e only 7.0% reduction compared to control. In the control where male and female adults were from normal population 90.1% hatchability of eggs was observed.

## DISCUSSION

*Helicoverpa armigera* Hubner, a major pest on chickpea, has assumed major status because of its high fecundity, multiple generations, high generation turn over, polyphagy and migratory behavior. Although it attacks chickpea throughout the crop growth, the damage caused during flowering and pod formation stages results in substantial losses. To combat this pest till now the thrust was given mainly on chemicals, however their indiscriminate use resulted in the development of pest resistance, resurgence, environmental pollution, besides having adverse effects on bioagents. This ultimately led to adopt an appropriate IPM programme. Present studies were carried out in field and laboratory during *rabi* 1998-99 & 1999-2000 at ICRISAT Center, Patancheru, A.P. with a view to develop suitable and sustainable IPM strategies against *H.armigera* on chickpea by considering their safety against natural resources. The results of the experiments conducted are discussed in this chapter with the available literature.

### 5.1 FIELD STUDIES

#### 5.1.1 Population Fluctuations of *H.armigera* in Chickpea

A sound knowledge on the population fluctuations of the chickpea pod borer helps to evolve suitable pest management strategies.

During *rabi* 1998-99 the peak moth activity was observed during initiation of flowering stage which was one week before the peak oviposition. During *rabi* 1998-99 the maximum number of eggs (Figure.16) and small size (Figure.17) larvae were observed during flowering stage of the crop with peaks at 50 & 57 DAS, respectively, which did not influence the yield directly. Medium (Figure.18) and large (Figure 19)

Fig. 16 : Effect of the treatments on oviposition behaviour of *H. armigera* during rabi 1998-99.

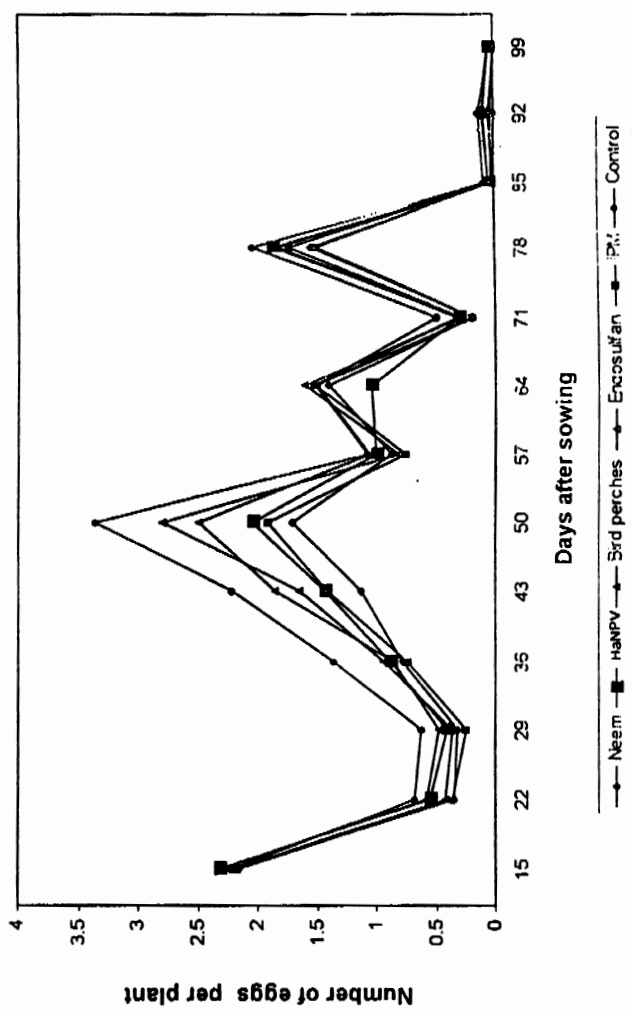
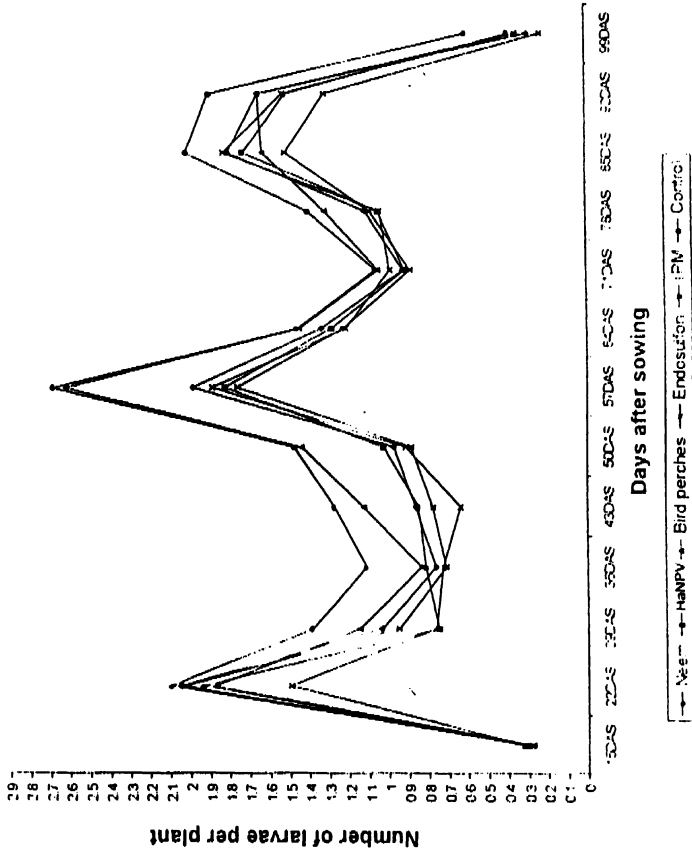




Fig. 17 : Small larval population of *H.armigera* throughout the crop season in different treatments during rabi 1998-99



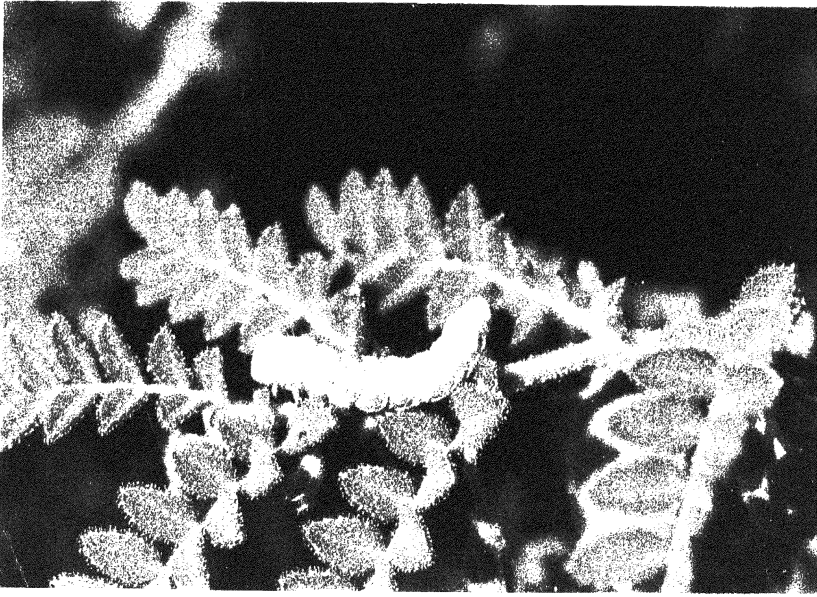


Plate 9 : Larva of *H. armigera* on the chickpea foliage.

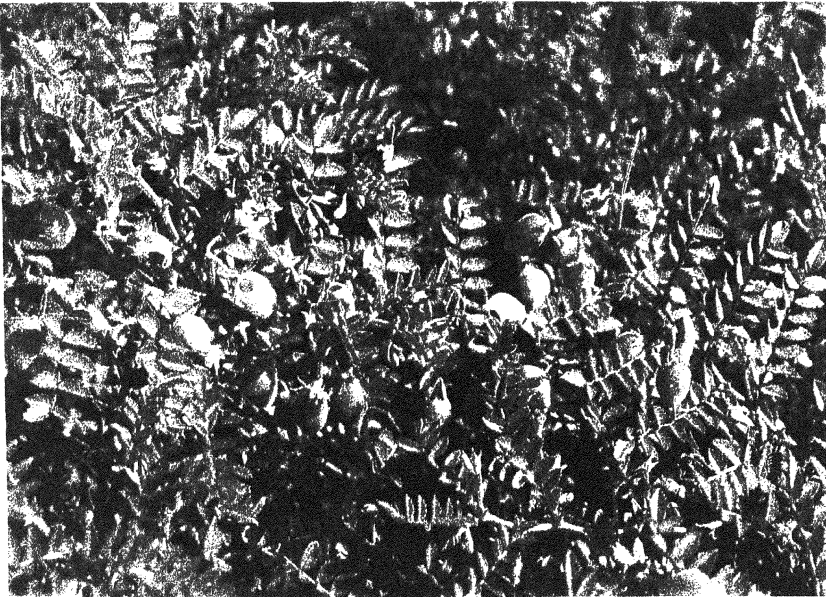


Plate 10 . Pod damage due to *H. armigera*.

size larval populations were more at pod formation and preharvest stages, respectively, but the peak population was observed stage at 71 & 85 DAS respectively, which directly influenced the yield by enhanced pod damage (Plate.9&10). Even though the egg and small larval population were high during flowering stage and medium and large larval population during pod formation stage, there was more or less uniform population throughout the crop growth suggesting the immigration of pest population from other fields.

The larvae were observed throughout the cropping period from 15 DAS to 99 DAS, even though it attained three peaks at 29, 57, 85 DAS the highest was at 57 DAS i.e first week of January which coincided with flowering & pod initiation stage. The pest activity started in the second fortnight of November and continued till the end of February (Figure.20).

During *rabi* 1999-2000 also the population fluctuation trend of *H.armigera* followed more or less the same as that of *rabi* 1998-99. The maximum moth activity was observed at initiation of flowering stage i.e one week before the maximum egg laying and remaining two peaks at 90 and 97 DAS, respectively. The maximum number of egg (Figure.21) and small larvae (Figure.22) of *H.armigera* were observed during flowering stage of the crop with peak at 54 days after sowing. Medium (Figure.23) and large (Figure. 24) size larval populations were more at pod formation stage, with peak population at 83 and 90 DAS, respectively, which directly caused the economic damage to the crop.

The larvae were observed in the field from 24 DAS to 112 DAS, even though it attained four peaks at 54, 68, 75 and 90 DAS the highest at 68 DAS i.e last week of December which coincided with pod formation

Fig. 18 : Medium larval population of *H.armigera* throughout the crop season in different treatments *rabi* 1998-99

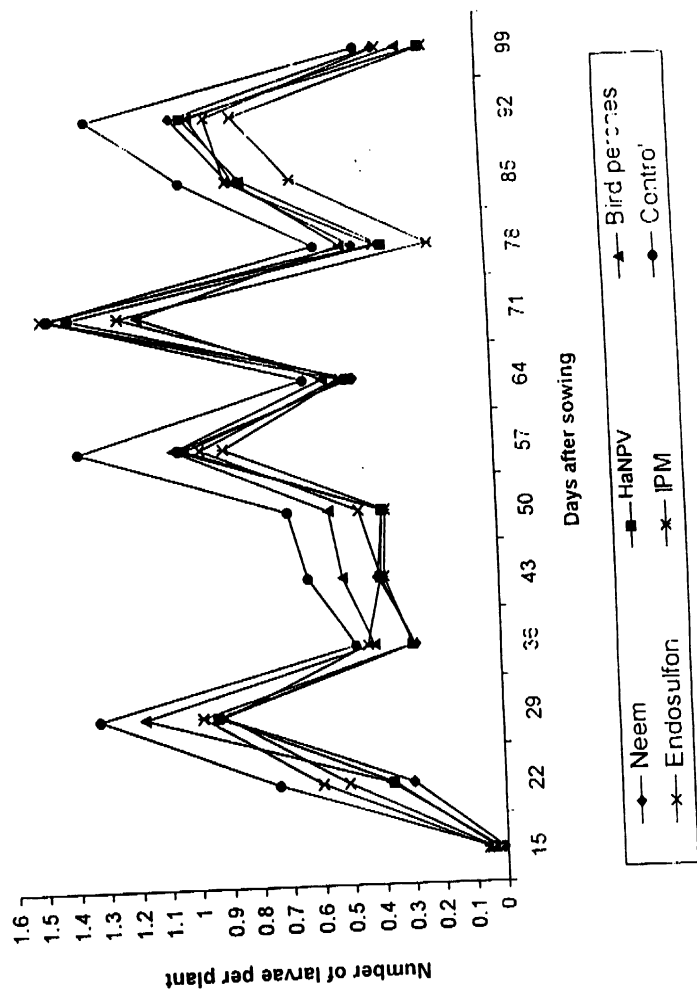


Fig.19 : Large larval population of *H.armigera* throughout the crop season in different treatments during rabi 1998-99

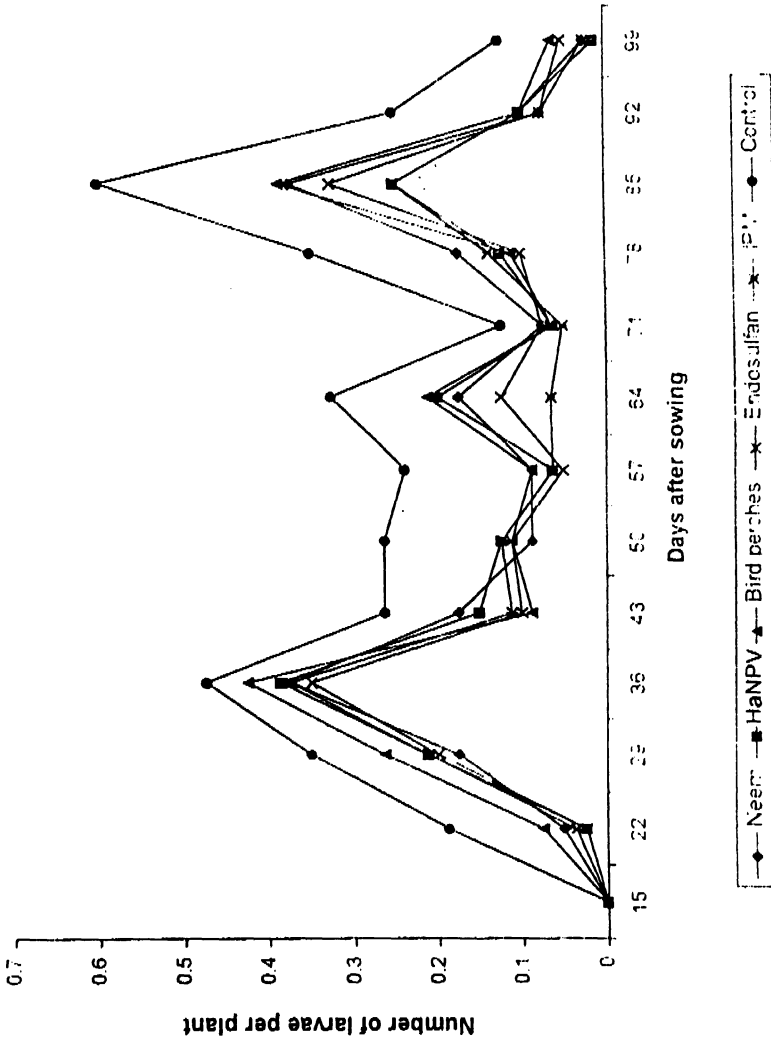
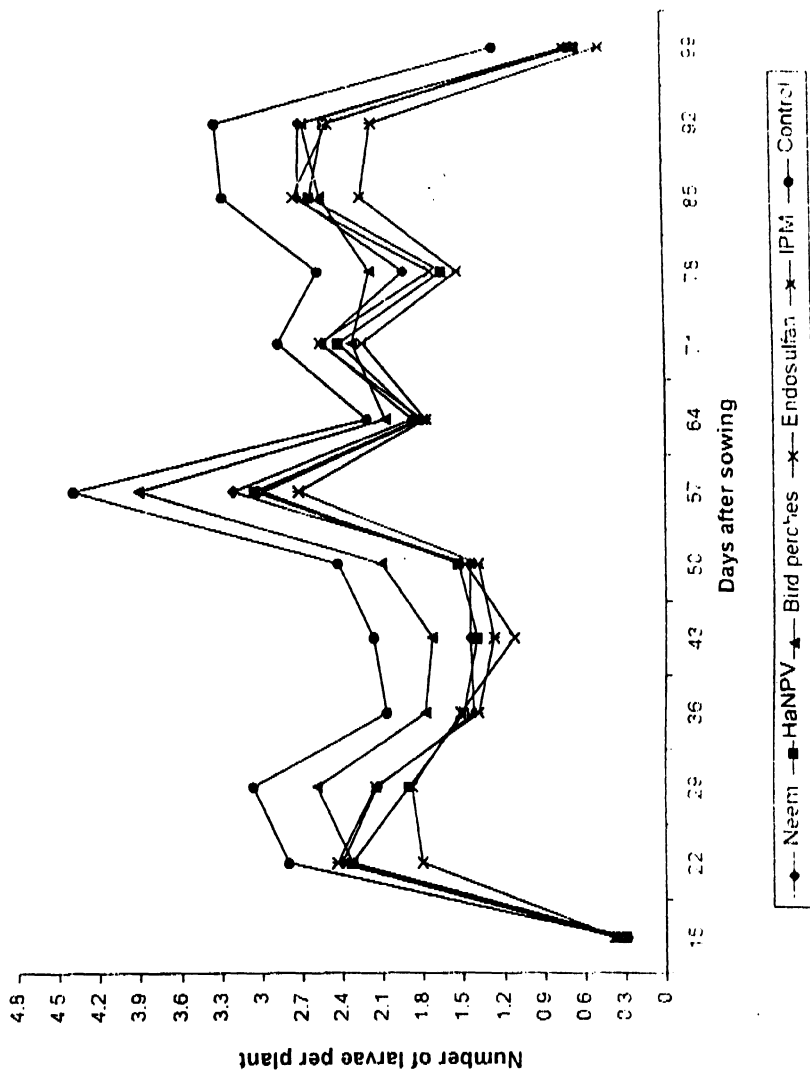


Fig.20 : *H.armigera* larval population throughout the crop season in different treatments during rabi 1998-99



stage. The pest activity started in the second fortnight of November and continued till harvest i.e first week of February (Figure.25).

Mahajan *et al.* (1990) observed the maximum pheromone catch during 3<sup>rd</sup> and 5<sup>th</sup> meteorological week, but in the present study during *rabi* 1998-99 it was observed at 51<sup>st</sup> meteorological week and during *rabi* 1999-2000 at 3<sup>rd</sup> meteorological week.

Thakur (1990) observed the infestation of *H.armigera* on chickpea from 3<sup>rd</sup> week of October and first week of November upto the middle of March and also recorded the highest population in second week of December and the 2<sup>nd</sup> peak in first and 3<sup>rd</sup> week of January. Yadava and Lal (1988) reported two peaks in the *H.armigera* population in chickpea during the 47<sup>th</sup> to 50<sup>th</sup> and 11<sup>th</sup> to 15<sup>th</sup> standard weeks. The finding of the present studies were in conformity with the above reports.

On the overall basis the pest load was comparatively low during *rabi* 1999-2000 season compared to *rabi* 1998-99 which could be due to early sowing of the crop. The alteration of the sowing date itself is one of the IPM components. Chaudhary and Sachan (1995) conducted experiments during *rabi* 1990-91 and 1991-92 in chickpea and stated that October sown crop has the lowest population of *H.armigera* (0.42-0.5 larva/m row) and the greatest grain yield whereas November sown crop had the greater number of insects and lowest yield irrespective of insecticidal use. According to Prasad and Singh (1997) chickpea crop sown on 25<sup>th</sup> September produced more yield, and recorded lower incidence of *H.armigera* compared to the sowing on 10<sup>th</sup> October. Both the above reports support the present finding.





Figure.22 : Effect of the treatments on small size larvae of *H.armigera* during rab, 1999-2000

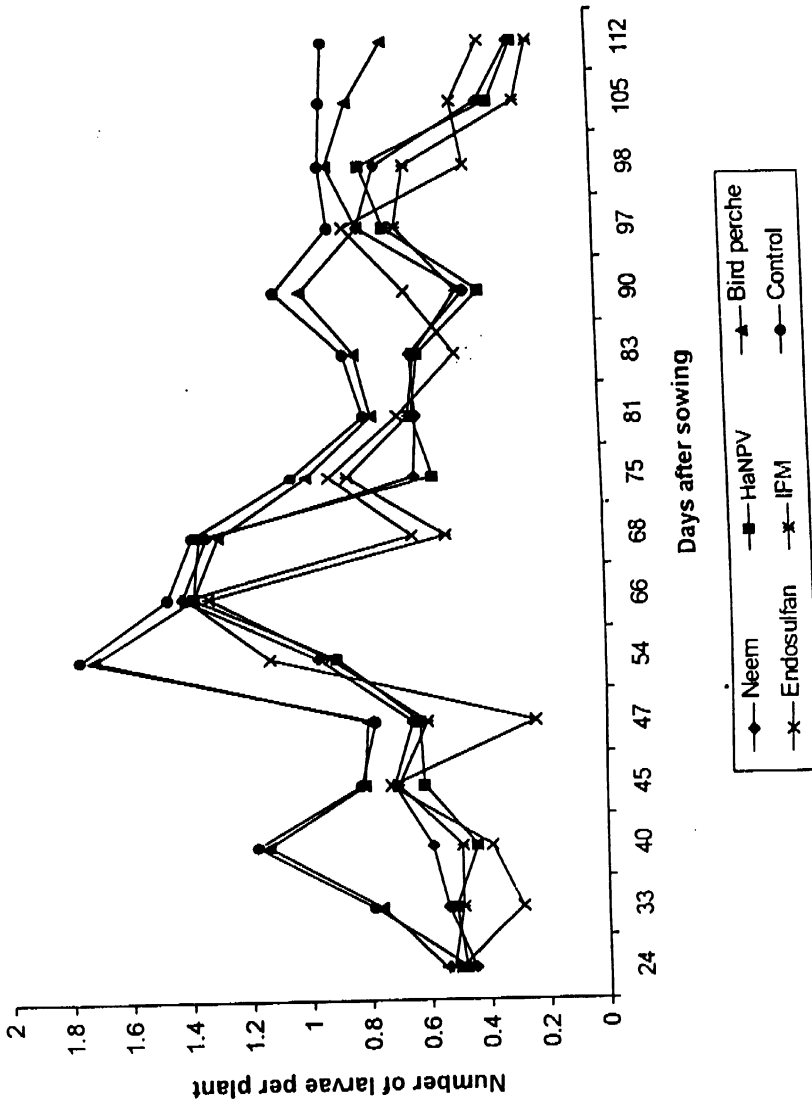


Fig.23 : Effect of the treatments on medium size larvae of *H.armigera* during rabi 1999-2000

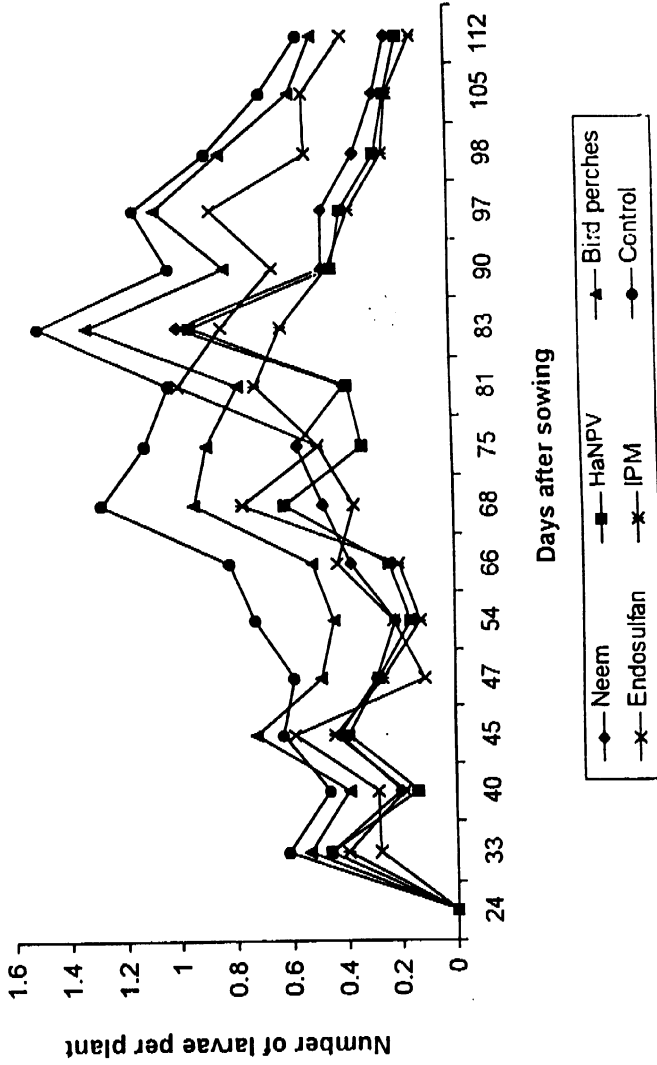
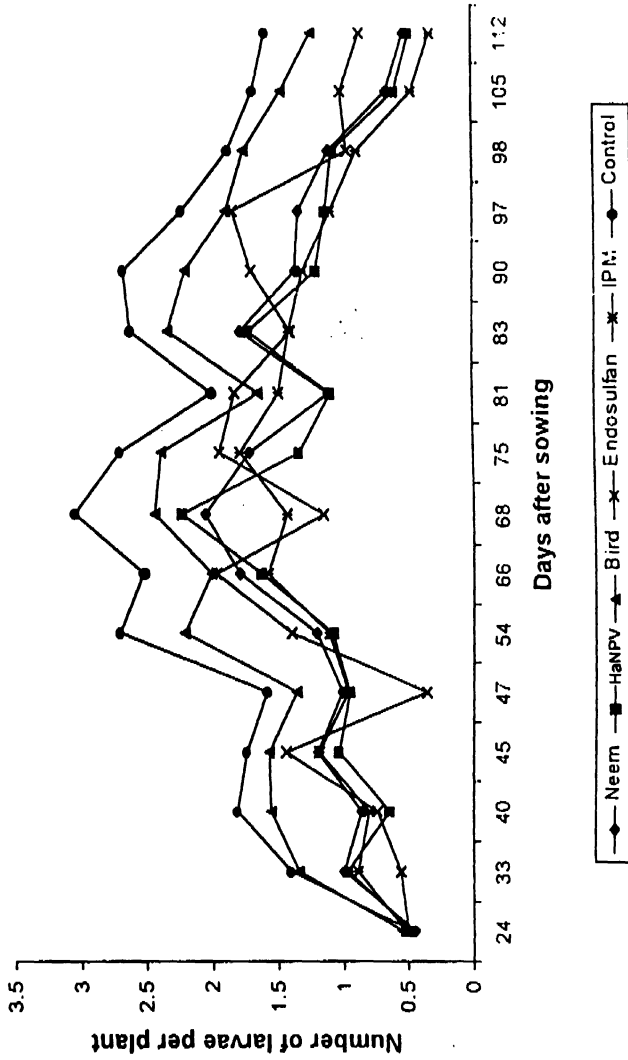




Fig. 25: Effect of the treatments on *H.armigera* total larval load during rabi 1999-2000



### 5 1.2 Efficacy of the treatments on the ovipositional preference of *Helicoverpa armigera*.

During *rabi* 1998-99, at all the stages of crop growth period neem was the best effective treatment in reducing the oviposition of *H.armigera* on chickpea. Neem treatment gave 47, 33 and 30 per cent reduction of egg laying in comparison with control during vegetative, flowering and podding stages of the crop and complete reduction of egg laying during preharvest stage of the crop. IPM was the next best treatment which received neem as first and fourth spray with 29 to 86 per cent reduction of egg laying compared to control. Endosulfan also showed its efficacy in reducing egg laying by *H.armigera* moths during vegetative, podding and preharvest stages but not at flowering stage, particularly endosulfan showed its effect till few days after the treatment. Since IPM is a combination of neem, HaNPV, bird perches and endosulfan spray, it was found to be equally effective as that of neem as ovipositional deterrent.

During *rabi* 1999-2000 neem proved as the best ovipositional deterrent against *H.armigera*, and provided significant protection to chickpea crop from pod borer throughout the crop period, with lowest mean number of eggs in all the stages of the crop i.e 86, 67, 87, 100 per cent reduction of egg laying compared to control during vegetative, flowering, podding and preharvest stages of the crop, respectively. IPM which received neem as first and fourth spray also effectively reduced the percentage egg laying compared to control (32 to 100%). Endosulfan also showed some effect in reducing oviposition by *H.armigera* moths particularly immediately after spraying.

The ovipositional deterrent effect of azadirachtin was confirmed by Warthen (1979); Redfern *et al.* (1981); Rembold (1984) and Schmutterer

(1990); Murugan *et al.* (1995). Jeyakumar and Gupta (1999) reported that the neem seed kernel extract 10 & 7.5% treatment reduced the oviposition to 60.9 and 59 per cent by *H.armigera* compared to control. Ramachandra Rao *et al.* (1990) also reported the ovipositional repellent effect of neem products. The report by Rosaiah (1992) on the maximum oviposition repellency of Repellin, a neem product, to *H.armigera* on cotton also strengthen the present observation on the oviposition repellency of neem to *H.armigera* on chickpea.

### **5.1.3 Efficacy of the Treatments in Managing Small Size Larval Population of *H.armigera*.**

During *rabi* 1998-99 endosulfan as a chemical was the most effective treatment in managing small size larvae (first & second instars) during vegetative stage with 38% reduction compared to control. But in the remaining stages of the crop i.e flowering, pod formation and preharvest stages IPM was the superior treatment with 31, 22, 79 per cent reduction compared to control, respectively. During vegetative stage IPM was on par with neem because in the first spraying it received neem. HaNPV and neem showed equal efficacy in managing small size larvae with a range of 14 to 26 per cent reduction compared to control. Bird perches showed no significant reduction of small size larvae compared to control during flowering, pod formation and preharvest stages.

During *rabi* 1999-2000 also endosulfan was the most effective treatment in managing small size larvae during vegetative stage with 50% reduction compared to control. Whereas neem was superior during flowering with 40.7% reduction of the larvae compared to control. This may be due to good oviposition deterrent effect of neem, which ultimately lead to less infestation. IPM was superior treatment during pod formation

and preharvest stages in keeping small size larvae at low level with 40 and 51% reduction compared to control, respectively. HaNPV was equally effective as that of endosulfan (7 to 44% reduction compared to control) in managing small size larvae. Bird perches showed no effect in managing small size larvae of *H.armigera*.

IPM initially did not show its superiority but later when it continued to receive different IPM components one after another, its superiority was observed.

Reports regarding the effect of different IPM components on small size larvae of *H.armigera* are not available.

#### **5.1.4 Efficacy of the Treatments in Managing Medium Size Larval Population of *H.armigera*.**

During *rabi* 1998-99 initially during vegetative stage due to its antifeedant and growth inhibiting effects, neem showed its superiority in managing medium size larvae of *H.armigera* with 40 per cent reduction compared to control followed by HaNPV with 37.5 per cent reduction compared to control. But during the remaining stage of crop, IPM treatment held its superiority in keeping medium size larvae at low level with 34.7, 32.6 and 41.5 per cent reduction over control during flowering, pod formation and preharvest stages, respectively. HaNPV showed superior effect than even endosulfan with 17 to 38 per cent reduction compared to control. HaNPV showed less effect at podding stage which may be due to presence of majority of medium size larvae in the pods and less access to potential POBs. Neem showed more effect at vegetative and flowering stages compared to remaining stages. Erecting bird perches was found to be as effective as endosulfan with 19 to 28 per cent reduction over control in different crop stages.

During *rabi* 1999-2000 IPM and HaNPV treatments proved superior in managing medium size larvae with 45 to 72% reduction compared to control. Even though endosulfan given high initial kill, on the overall basis, neem showed superior effect compared to endosulfan with 42 to 60% reduction over control. Whereas endosulfan gave 29 to 64% reduction over control. Installation of bird perches was found useful by reducing 8 to 32% larval population compared to control.

Parasharya (1995) reported that birds prefer medium and large size larvae and assist in the spread of insect pathogens by eating NPV infected larvae, this report support the significant effect of bird perches in reducing medium size larvae compared to control in both the seasons. Reports regarding the effect of remaining IPM components on medium size larvae of *H.armigera* are not available.

#### **5.1.5 Efficacy of the Treatments in Managing Large Size Larval Population of *H.armigera***

During *rabi* 1998-99 IPM maintained its supremacy in managing the fifth and sixth instar larvae of *H.armigera* by registering 47, 70, 59 and 84 per cent reduction over control in vegetative, flowering, podding and preharvest stages, respectively, followed by endosulfan with 47 to 84 per cent reduction compared to control. Neem and HaNPV showed almost similar efficiency by recording 39 to 87 percent reduction over control except at pod formation stage where HaNPV showed less efficiency. Erecting bird perches also reduced the larval number significantly compared to control and it was as effective as neem and HaNPV in managing large size larval population of *H.armigera*.



During *rabi* 1999-2000 during vegetative stage HaNPV was superior in managing large size larvae, but later in the remaining stages of crop growth IPM maintained its superiority with 35 to 90% reduction of larval population compared to control followed by HaNPV which also produced similar effect with that of IPM. At vegetative stage IPM was on par with neem because it received neem as first spray. Endosulfan and neem gave more or less uniform control with 24 to 85% reduction over control during various crop stages. Bird perches also proved effective and gave 28 to 66% reduction of large size larval population compared to control.

Parasharya (1995) reported that birds prefer medium and large size larvae and assist in the spread of insect pathogens by eating NPV infected larvae, this report support the significant effect of bird perches in reducing large size larvae compared to control in both the seasons. Reports regarding the effect of remaining IPM components on large size larvae of *H.armigera* are not available.

#### 5.1.6 Efficacy of the Treatments in Managing *H.armigera* Total Larval Load

During *rabi* 1998-99 initially at vegetative stage endosulfan showed its superiority in reducing total larval load with 37% reduction compared to control. But in the remaining stages of crop growth IPM stood as a better treatment with 35, 31 and 43 % reduction over control during flowering, podding and preharvest stages, respectively. Based on average larval load in different crop stages the effect of endosulfan almost equaled to HaNPV and neem. Bird perches even though were inferior compared to other treatments, contributed 11 to 26 % reduction of larval load compared to control without any investment.

During *rabi* 1999-2000 at vegetative stage of the crop HaNPV proved more effective with 47% reduction of total larvae compared to control. But in the remaining period of the crop growth IPM plots were found superior with 46, 43 and 62% reduction of larval population compared to control during flowering, pod formation and preharvest stages of the crop, respectively. HaNPV gave more or less equal control as that of IPM during flowering and pod formation stages of the crop. Even though endosulfan was superior in managing total larvae during vegetative and flowering stages, its effect was almost similar to neem during pod formation stage. Even though bird perches showed inferior effect compared to other treatments, it was found significantly superior compared to control and contributed 14 to 37% reduction of total larval load compared to control especially medium and large size larvae which had profound influence on the yield.

Thakur *et al.* (1988) reported that neem kernel extract and leaf extract recorded significantly less larval population in comparison to control, however it was less effective compared to chemicals and concluded that it can be used in place of highly toxic synthetic insecticides. Sehgal and Ujagir (1990) & Datkhile *et al.* (1992) stated that NSKE at 5% was less effective on gram pod borer *H.armigera* when compared to endosulfan but still significantly better than the control. The above reports support the present findings with regard to the superiority of endosulfan over neem in controlling small and medium size larvae, but on the overall basis neem was equally effective as that of endosulfan. This was supported by Sinha (1993) who reported that NSKE 5% gave 40% reduction of infestation of *H.armigera* in chickpea and was comparable to endosulfan 0.07%.

Anitha Mistry *et al.* (1984) reported that five sprays of HNPV @ 250 LE/ha gave satisfactory control of *H.armigera* in chickpea. Jayaraj *et al.* (1987) also found significant control of chickpea pod borer due to HNPV @ 250 LE/ha. The observations of Pawar *et al.* (1987) on the effectiveness of HNPV on chickpea pod borer, compared with endosulfan spray corroborate the present findings.

The findings of Ghode *et al.* (1988) on the high avian predation of *H.armigera* by cattle egrets and river tern in the month of January support the present findings, besides this, ICAR (1992) also reported 33% reduction of *H.armigera* population by birds on wheat and 20-40% only by house sparrow. In this study bird perches reduced only medium and large size larvae. Parasharya (1995) reported that birds prefer medium and large size larvae and assist in the spread of insect pathogens by eating NPV infected larvae. This report supports the present findings of heavy reduction of larval population of *H.armigera* in IPM plots, when HaNPV was sprayed twice apart from bird perches to encourage the predation by birds.

According to Sanap and Pawar (1998) IPM treatment for controlling *H.armigera* in gram includes three spray applications starting from initiation of flowering and subsequent two sprays at 15 days interval with first two sprays either with HNPV @ 250 LE/ha or NSKE 5% followed by a third spray with endosulfan 0.07% were most effective, this report support the present finding of superiority of IPM.

#### 5.1.7 Effect of the Treatments on Natural Enemies Present in Chickpea Ecosystem

One of the main reasons for failure of pest control with chemicals is the destruction of natural enemies present in the agro-ecosystem which leads to pest build up in the absence of natural control. So at this

junction it is necessary to incorporate plant protection options into IPM system which are safer to natural enemies of the pest. For this reason the present study evaluated the effect of selected IPM components individually and in combination on the natural enemies fauna present in the crop.

#### 5.1.7.1 Effect of the treatments on soil inhabiting natural enemies

During *rabi* 1998-99 endosulfan treatment significantly reduced the ground dwelling natural enemies at all stages of the crop growth with 60 to 75% reduction compared to control up to pod formation stage. Neem spray also caused 8 to 50% reduction compared to control where as IPM recorded 54% reduction during flowering stage, which may be due to application of endosulfan during this stage. IPM also recorded 36, 25% reduction of natural enemies during vegetative and podding stage, respectively but no reduction was observed during preharvest stage. The reduction of natural enemies in IPM plot was mainly due to application of endosulfan as third and neem as first and fourth sprays. Even though the treatments with HaNPV and bird perches recorded little reduction of natural enemies throughout the crop period compared to control it was not significant, hence were concluded as safer to the soil dwelling natural enemies. Thus it was concluded that chemical as well as neem to some extent affect the natural enemy fauna in the chickpea while the remaining components were safer.

During *rabi* 1999-2000 endosulfan treatment once again proved to be a harmful component of IPM to soil dwelling natural enemies with 65, 47, 63 and 75% reduction over control during vegetative, flowering, pod formation and preharvest stages, respectively. Neem caused a significant reduction at flowering and pod formation stages with 40 and 38% reduction

compared to control, respectively. IPM treatment caused a significant reduction at flowering and pod formation stages with 26 and 62% reduction only compared to control, respectively, where it received endosulfan and neem treatments. IPM treatment did not show any significant effect on number of natural enemies at vegetative and preharvest stages. HaNPV and bird perches caused little disturbance but not at significant level compared to control at flowering and pod formation stages and were relatively safer to natural enemies. During peak period of birds activity some reduction in natural enemies fauna was observed which was not significant.

Parmar (1993) reported that neem can be used in IPM system because of its relative safety compared to highly toxic chemicals. According to Krishnamoorthy (1995) several insecticides including endosulfan were found toxic to both larvae and adults of *C. carnea*. Both spider and ground beetle populations were known to be reduced by regular applications of insecticides (Pfrimmer, 1964). Bijjur *et al.* (1991) reported that *Apis cerana indica* did not show any signs of abnormal development due to its exposure to NPV. All the above statements support the present findings of harmful nature of endosulfan and relative safety of HaNPV on natural enemies present on ground as well as on crop foliage.

#### **5.1.7.2 Effect of the treatments on natural enemies present on crop canopy during *rabi* 1998-99**

Among the treatments endosulfan spray was found to have more effect on natural enemies present on crop canopy and reduced significantly both at 22 DAS and 54 DAS with 54 and 58% reduction over control, respectively. Where as neem was found to reduce significantly at 22 DAS because of its repellent action on natural enemies, but at 54 DAS it did not cause any significant reduction. Bird perches did not show any

significant effect. In IPM there was 19% reduction of natural enemies at 22 DAS mainly due to neem and 47% reduction at 54DAS due to endosulfan which was given as third spray in IPM. HaNPV had negligible effect.

According to Krishnamoorthy (1995) several insecticides including endosulfan were found toxic to both larvae and adults of *C. carnea*. This report support the toxic effect of endosulfan to natural enemies present on foliage as observed in the present study. Bijjur *et al.* (1991) reported that *Apis cerana indica* did not show any signs of abnormal development due to its exposure to NPV, and this observation support the present results in which NPV did not show side effects on natural enemies present on foliage.

#### 5.1.7.3 Effect of the treatments on the natural parasitism of *H.armigera*

During both the seasons the egg parasitisation was observed to be nil. The dead *Trichogramma* adults were noticed on 10-15% of the chickpea plants, which indicate the non suitability of chickpea habitat for survival and effectiveness of *Trichogramma* species due to acid exudates. This was supported by report of Yadava *et al.* (1985) who reported that inundative release of *T.chilonis* to control *H.armigera* was found ineffective in chickpea, and Bhatnagar (1981) confirmed the deterrent role of leaf exudates of chickpea on the activity of egg parasitoid *Trichogramma*.

During *rabi* 1998-99 a significant reduction of natural parasitisation by *C. chloridae* (27%) was observed at 25 DAS i.e 4 days after endosulfan treatment. Neem and IPM which received neem as first spray significantly reduced the natural parasitism by *C.chloridae* to 38 and 33%, respectively

compared to control. Where as in the remaining treatments no significant reduction of parasitism was observed. At 58 DAS that is 6 DAT there was no significant difference among the treatments for the larval parasitism by *C. chloridaeae*. Except endosulfan all the other treatments were found relatively safer to *C. chloridaeae*. However endosulfan was found more toxic to larval parasitoid immediately after spray and later its toxic effect reduced drastically.

During the season a very low incidence of larval-pupal parasitoid *C. illota* was observed. It was found to be 2% only in control plot in 58 DAS sampling.

During *rabi* 1999-2000 at 36DAS i.e 4 days after treatment, only endosulfan spray significantly reduced the larval parasitism by *C. chloridaeae* to the extent of 42% compared to control. Whereas the remaining treatments were found to reduce parasitism to some extent but not significantly compared to control. At 68 DAS i.e 6 DAT there was no significant difference among the treatments for the larval parasitism by *C. chloridaeae*. The incidence of *C. illota* was only 4%.

Nagarkatti (1981) reported 20-80% larval parasitisation by *C. chloridaeae* and observed the maximum during December and January months. In the present study the parasitism level was 11% during first fortnight of December and 7% during first fortnight of January in *rabi* 1998-99 and during second fortnight of November 5% and 10% during second fortnight of December in *rabi* 1999-2000. These findings are in agreement with Yadava (1990) who reported 10% parasitisation of *C. chloridaeae* on *H. armigera* in chickpea with peak activity between September and February.

### 5.1.8 Effect of the Treatments on Pod Damage by *H.armigera*

The perusal of the data during *rabi* 1998-99 revealed that IPM and endosulfan were found to be the best treatments by recording the lowest percentage of pod damage with 47 and 43% reduction compared to control, respectively. Neem and HaNPV gave similar protection to crop from pod damage by *H.armigera*. Bird perches also reduced the pod damage up to 27% compared to control since the birds activity was more at ICRISAT Center due to prevailing favourable conditions for their survival. The per cent pod damage was observed to be low in IPM due to contribution of all IPM components.

During the *rabi* 1999-2000 endosulfan was proved to be the best treatment with 49.7 % reduction of pod damage compared to control. IPM and endosulfan were at par in reducing pod damage. Neem and HaNPV were found equally effective in reducing pod damage followed by bird perches. Bird perches contributed to the extent of 31% reduction of pod damage compared to control.

Thakur *et al.* (1988) reported 13 and 5% pod damage at green pod and harvest stages respectively in neem leaf extract 5% treatment and 3 and 4% in NSKE 5% treatment. Pawar *et al.* (1990) reported 46% reduction in pod damage by *H.armigera* over control when HNPV @ 250 LE/ha was sprayed twice in chickpea. Saxena (1980) reported the promising role of birds to reduce pod damage by *H.armigera*. The pod damage of 1.4% to 14% due to application of endosulfan against *H.armigera* in chickpea was reported by Sanap and Deshmukh (1987) and Ujagir *et al.* (1997). The pod damage was observed to be 6.7% when endosulfan 0.05% was sprayed after NPV @250LE/ha in chickpea against *H.armigera* (Pawar *et al.*, 1990).



All the above reports suggested that the pod damage caused by *H.armigera* can be reduced by different IPM components individually and contributed in a synergistic manner to reduce the pod damage when given in combination in IPM plot with out any harmful effects associated due to use of chemicals.

#### 5.1.9 Effect of the IPM Options on Chickpea Yield

During *rabi* 1998-99 the results suggested 60% extra yield in IPM plot followed by 42% yield increase in plots treated with endosulfan compared to untreated area. HaNPV and neem were found equally effective and gave around 30% extra yield compared to control. Plots installed with only bird perches gave 15% extra yield compared to control.

During *rabi* 1999-2000 season endosulfan treated plot recorded 63% additional yield compared to control followed by IPM with 59% additional yield over control. HaNPV and neem were found equally effective, and bird perches also contributed 28% extra yield compared to control.

From the results it was clear that birds activity was more during *rabi* 1999-2000 than the previous year. But the contribution of birds may not be to this extent in farmers fields because of the favourable conditions for birds activity present in ICRISAT may not prevail in farmers fields, however one should try to take advantage of these natural resources.

Thakur *et al.* (1988) reported 31% yield increase due to NSKE 5% treatment in chickpea against *H.armigera* which was in agreement with the present finding. Pawar *et al.* (1990) reported 14-47% yield increase due to HNPV @250LE/ha against *H.armigera* in gram. Birds contributed 218 g/m<sup>2</sup>

increase in yield of wheat (ICAR, 1992). The increase in yield by 45% in chickpea due to application of endosulfan 0.07% was reported by Thakur *et al.* (1988). Sanap and Pawar (1998) reported 26.9 and 27.3 % increase in yield during 1993-96 due to IPM treatment by controlling *H.armigera*. All the above reports support the present findings of yield increase due to different IPM components which contributed in a synergistic way in IPM plot

#### 5.1.10 Economics of the IPM Components

During both the years bird perches showed the highest cost-benefit ratios due to less cost involved, but showed very less increase in yield compared to control. During *rabi* 1998-99 the highest cost benefit ratio was obtained with IPM treatment (1:2.3) followed by endosulfan (1:1.81). During *rabi* 1999-2000 also IPM gave highest cost benefit ratio of 1:3.76 followed by endosulfan (1:3.71). Even though HaNPV recorded the lowest cost benefit ratio due to its high cost of production it can be reduced by educating the farmers about its preparation. Even for neem also if the farmers prepare NSKE at farmhouse itself with locally available neem seeds the cost of production can be minimized which inturn increases the C:B ratio. All these finally reduce the cost of plant protection of IPM and it may prove much better than chemical treatment.

The cost benefit ratio of endosulfan 0.07% was reported as 1:5.2 by Parsai *et al.* (1989), as 1:12 by Gupta *et al.* (1991) in chickpea against *H.armigera*. Thakur *et al.* (1988) also recorded the highest C:B ratio of 1:10 with endosulfan 0.07%, with NSKE5% as 1:7.7 and with neem leaf extract 5% as 1:3.9. Datkhile *et al.* (1996) reported that endosulfan 0.07% gave 1:5.3 C:B ratio where as it was 1:2.6 for HNPV @250LE/ha, 1:2.7 for neemark 0.2% and 1: 2 for NSKE in chickpea. All these reports conform the superiority of endosulfan compared to neem and HaNPV. Reddy and Manjunatha (2000) conducted experiment in consolidated block of 40 ha

cotton fields at two locations and demonstrated the superiority of IPM strategy in terms of both cost versus benefit ratio and environmental safety over that used in the farmers fields where only conventional control methods were followed. This report confirm the superiority of IPM in C:B ratio in the present experiment.

In the present study the cost of neem and HaNPV was considered along the market price and there is every possibility of producing them at farm level hence the C:B ratio with these treatments can be improved.

#### 5.1.11 Residues of Chemicals

Plants treated with endosulfan contained 0.81mg/kg residue in seed and 1.35 mg/kg in husk at harvest stage of the crop but no residues were found in IPM treatment plot. Even though the residues are less than the maximum residual limit given by FAO but may affect the health of consumers to some extent if consumed at green pod stage and the animals if they consumed green foliage of chickpea. This risk must be kept in mind while using chemicals on crops like chickpeas.

Pandey *et al.* (1977)<sup>b</sup> reported presence of residues at much higher than the tolerance limit even 25 days after spraying of endosulfan 0.07% both in plant and grain of chickpea and also reported the translocation and accumulation of residues in the grain. Verma (1983) stated that the residues of endosulfan fell below the tolerance limit in 12 days in grain after spraying with endosulfan 0.07%, and this report confirm the results in the present experiment.

## 5.2 LABORATORY EXPERIMENTS

### 5.2.1 Oviposition Deterrenncy Effect of Neem Against *H.armigera*

The present studies clearly demonstrated the ovipositional deterrenncy effect of neem against *H.armigera*. There was a significantly lower mean number of eggs laid per pot (two plants) which were sprayed with neem 60 ppm compared to water sprayed pots (111.60, 287.8 eggs respectively).

This was in confirmity with the results of Jeyakumar and Gupta (1999) who reported that NSKE 10 and 7.5% treatments reduced oviposition by 60.9 and 59 % compared to control by *H.armigera* in chickpea. Present field results also support this statement that neem effectively deterred the egg laying by *H.armigera*.

### 5.2.2 Antifeedant Effect of Neem Against *H.armigera*.

When different age groups of *H.armigera* were given choice to choose their food between neem treated and untreated chickpea leaves and pods their capacity to differentiate was increased with age of the larvae. The data showed that the small larval group (first & second instars) did not show any significant differentiation between neem treated and untreated food, where as the medium sized group (third & fourth instars) and large sized group (fifth & sixth instars) showed significant differentiation between neem treated and untreated food.

When the *H.armigera* larvae were given neem treated food under no choice situation the initial behavior was more pronounced in older larvae with faster movement around the food, and tried in search of any other food. Since there was no alternative food the larvae finally settled on the neem treated food. It was clear that 40% of older larvae, 20% of medium sized larvae and none of the younger larvae showed initial avoidance of neem.

The above two experiments clearly indicated the antifeedant effect of neem on *H.armigera*. Contact with azadirachtin makes disruption in food intake and increases the locomotory activity of insects as reported by Schoonhoven *et al.* (1987) which was also observed in the present study. The antifeedant effect of neem extract was also reported by Murugan *et al.* (1993).

### 5.2.3 Effect of Neem on Different Age Groups of *H.armigera*

Unlike a chemical which cause direct kill of larvae neem shows different types of effects like repellency, feeding & oviposition deterrency and hormone like growth disrupting activity throughout the lifecycle of the pest and even affect fecundity also.

In the present study the results suggested that the effects of neem were more pronounced when *H.armigera* received treatment at early age. There was about 40% mortality in small larvae and 10 % in medium larvae and no mortality was recorded in large larvae.

Larval duration was significantly increased when fed with neem in all the three age groups compared to control. But even with more larval duration it can not cause more damage to crop because it suffers with several abnormalities like disruption of cuticle, reduced food intake and even activity also.

Pupal weight was significantly reduced in first and second age groups but not in third age group because of less time to experience the neem effect. Due to less food intake, reduced growth index, efficiency of conversion of ingested food and efficiency of conversion of digested food leads to reduced pupal weight compared to control.

The effective oviposition period and fecundity were reduced in all the three age groups significantly compared to control. Where as no significant effect was observed in egg hatching with neem. Reduced fecundity in *H.armigera* due to NSKE was observed by Joshi and Sitaramaiah (1979) and reduced fecundity and hatching was also observed by Brattsen (1983) which confirmed the present results.

According to El-Sayeed (1985) 0.2-0.5% suspension of ground neem seeds caused complete mortality of *S. littoralis* by the end of larval period and also caused pupal mortality and adult deformity. Growth inhibitory effect of neem limnoids in *S.litura* was reported by Murugan and Jeyabalan (1995) confirming the effects of neem which were observed during the present experiment.

#### **5.2.4 Efficacy of Robin Blue as an Ultraviolet Ray Protectant to *Heliothis armigera* Nuclear Polyhedrosis Virus**

Major obstacle in the use of insect viruses in field situations is the rapid inactivation by ultraviolet rays. The results suggested that robin blue is a good ultraviolet ray protectant. Several workers tried with different adjuvants and UV ray protectants to increase the persistence and effectiveness of HaNPV under field conditions. But detailed studies were not taken up with robin blue which was cheap and readily available and easy to use.

Immediately after treatment there was no difference between HaNPV + robin blue 1% and HaNPV treatments in their effect against third instar larvae of *H.armigera*. But at 24 hours after treatment due to addition of robin blue 16.67% extra mortality of III instar larvae of pod borer was recorded which shows the effectiveness of robin blue 1% in increasing the

persistence of HaNPV. Where as 2<sup>nd</sup> and 3<sup>rd</sup> day after treatment there was 15.48 and 16.67% extra mortality, respectively compared to HaNPV treatment with out robin blue. But at fourth day after treatment the effect of HaNPV was very low and found to be on par with control but due to the addition of robin blue significantly higher mortality compared to control was recorded. At 5<sup>th</sup> and 6<sup>th</sup> day after treatment the efficacy of HaNPV was almost nil but due to addition of robin blue significant effect compared to control was recorded.

Previously Rabindra and Jayaraj (1988) and Rabindra *et al.* (1989) reported increased efficacy of HaNPV with UV protectant like Robin blue which support the present findings.

#### 5.2.5 Effect of HaNPV on Different Age Groups of *H.armigera*.

Treatment of HaNPV @ $6 \times 10^9$  POB/l caused high mortality of *H.armigera* larvae at early stage compared to later stages indicating the capacity of larvae to with stand infection by HaNPV as age increases. This was supported by Ignoffo (1966) who reported that as the age of the *Heliothis zea* and *H.virescens* larvae increases their susceptibility to the HaNPV virus decreases.

When HaNPV treatment was given at first & second instar stage there was 100 % larval mortality, when it was given at third & fourth instar stage only 70% larval mortality but more pupal abnormality and death (97.9 %) was observed. In case of fifth & sixth instar stage the mortality was only 60 % but there was 87% pupal abnormality and death.

There was significant reduction in pupal weight when third & fourth instar larvae were fed with HaNPV. But this was not observed when larvae were treated with virus at fifth & sixth instar stage. This was supported by

Kencharaddi and Jayaramiah (1997). It was reported that the growth rate, gross and net efficiency of food utilization for body matter observed to be decreased during the course of HaNPV infection of *H.armigera* which ultimately leads to low pupal weight, but the time for showing this effect was less for fifth and sixth instar age group.

All these effects ultimately led to lower fecundity compared to control, where it was more pronounced in third & fourth instar age group compared to fifth & sixth instar age group. This finding was supported by Patil *et al.* (1989) where the HNPV treatment to *M.seperata* revealed an increase in development duration of larvae and pupae and also there was reduction in pupation, adult emergence rate, growth index, fecundity and average egg production, per cent egg hatchability. The same effects mentioned above were demonstrated in boll worm, *H.zea* by Luttrell *et al.* (1982).

#### 5.2.6 Effect of HaNPV Treatment on Fecundity of *H.armigera*

The moths collected from HaNPV treated population have less viability and capacity to mate. Most of the adults failed to emerge, some dead immediately after emergence, and some failed to mate and laid nonviable eggs, and, if mating occurred laid eggs only for few days and died.

When both male and female were collected from HaNPV treated population, there was significantly less number of eggs (689) compared to control (865). When only female was taken from HaNPV treated population, the fecundity was 718 eggs and with only male from HaNPV treated population the fecundity was 780 eggs compared to control (865).

This suggested the reduced fecundity of *H.armigera* by HaNPV treatment which was supported by the report of Luttrell *et al.* (1982) in the case of *H.zea*.



### 5.2.7 Effect of HaNPV Treatment on Egg Hatchability of *H.armigera*

A significant effect was observed on egg hatchability when larvae at fifth instar stage were treated with HaNPV. More significant reduction (30.5%) of hatchability was observed when male and female were taken from HaNPV treated population than with single sex from HaNPV. This result was supported by previous work of Patil *et al.* (1989) who observed the reduction of per cent egg hatchability in case of *M.separata* and Luttrell *et al.* (1982) in case of *H.zea* due to NPV treatment at larval stage.

## SUMMARY

Investigations were carried out on the effect of different IPM components on *H.armigera* and its natural enemies in chickpea ecosystem during 1998-99 and 1999-2000 *rabi* seasons at ICRISAT Center and the results obtained are summarized in this chapter.

1. The pest infestation was observed throughout the cropping period during both the years with peak population at 57 DAS i.e first week of January during *rabi* 1998-99 and at 68 DAS i.e last week of December during *rabi* 1999-2000 .
2. During both the years neem treatment effectively reduced the egg laying by *H.armigera* moths by acting as a oviposition deterrent and IPM which included neem as one of its component also effectively reduced the oviposition by *H.armigera* in chickpea under field conditions.
3. In both the years endosulfan was proved to be the best treatment in managing small size (first & second instars) larvae especially in the vegetative stage of the crop whereas IPM was superior in the flowering, pod formation and preharvest stages. HaNPV showed equal efficiency as that of neem during *rabi* 1998-99 but equally effective as that of endosulfan during *rabi* 1999-2000 in reducing the population of small size larvae.
4. IPM followed by HaNPV showed more effect in reducing medium size larvae in both the seasons than even endosulfan. Erecting bird perches was as effective as endosulfan in reducing medium size larvae during the peak period of bird activity.

5. At vegetative stage HaNPV was superior in managing large (fifth & sixth instar) larvae in *rabi* 1999-2000, but in the remaining period and during *rabi* 1998-99 throughout the crop period IPM maintained its superiority in managing the large size larvae. Erecting bird perches was as effective as endosulfan in reducing both medium and large size larvae during the peak period of bird activity.
6. Endosulfan and HaNPV proved effective in reducing total larval load during *rabi* 1998-99 & 1999-2000, respectively during vegetative stage but in the remaining stages IPM stood as a superior plant protection strategy in managing total larval load. Installation of bird perches contributed up to 26 and 37% reduction of larval load compared to control during the two years.
7. Endosulfan was observed to be harmful IPM component as it significantly reduced the total number of soil dwelling natural enemies in both the years and also the number of natural enemies present on crop canopy during *rabi* 1998-99. Neem also showed its ill effect on natural enemies and significantly reduced their number in both the seasons, present on ground as well as on foliage of the crop. Bird perches showed little disturbance to natural enemies during peak period of bird activity.
8. Egg parasitism by *Trichogramma* was not observed in both the years even though 10-15% of plants were observed with dead *Trichogramma* adults. Up to 11 and 10 % natural parasitism by *Campoletis chloredeae* Uchida, was recorded during *rabi* 1998-99 and 1999-2000 years, respectively. All IPM components except endosulfan were proved to be safe to natural parasitism by

*C.chloridae*. A very low level of larval-pupal parasitoid *Carcelia illota* Curron (2-4%) incidence was observed in both the years.

9. Even though endosulfan recorded the lowest pod damage and higher yield during 1999-2000, IPM treatment proved more economical than other components individually except bird perches with 1:2.30 and 1:3.76 cost benefit ratio's in both the years.
10. The plots treated with endosulfan were found to have residues of 0.81mg/kg in seed and 1.35mg/kg in husk at harvest stage, but in IPM plots the residues were found to be below detectable limit.
11. Neem effectively showed its oviposition deterrence effect with 111 60 eggs on neem treated foliage as against 287.8 eggs on control foliage which was 63% less.
12. When *H.armigera* larvae were given a choice to choose its food between neem treated and untreated food the capacity to differentiate increased with age of the larvae. When *H.armigera* was given neem treated food in no choice situations the searching behavior for another food source also increased with age.
13. Neem treatment showed different types of effects on *H.armigera* throughout its life cycle. The effects were more pronounced when treatment was given at early period of larval stage. The effects observed were increased larval duration, reduced pupal weight, reduced effective oviposition period and fecundity with no significant effect on egg hatching.

14. Robin blue 1% was proved to be a good ultraviolet light protectant and increased the persistence of HaNPV up to six days under field conditions with increased efficiency of HaNPV from 24 hours after treatment.
15. HaNPV @  $6 \times 10^9$  POB/l was found to have more impact on early stages of larvae than later stages. HaNPV treatment in addition to higher larval mortality resulted in pupal abnormality and death, reduced pupal weight, adult emergence.
16. When *H.armigera* larvae received HaNPV infection at fifth instar stage, they may escape from higher rate of mortality but the fecundity of adults was reduced up to 20% and the egg hatching up to 30%. The reduction in egg hatching was pronounced when male and female were from HaNPV treated population rather than of single sex from HaNPV treated population.

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\*Originals not seen

Note:- The literature is cited as per the "Thesis Guide lines" Prescribed by Acharya N.G.Ranga Agricultural University, Rajendranagar, Hyderabad.

**Appendix 1 : Efficacy of different IPM components on oviposition behaviour of *Haemigera* during rabi 1998-99 (No. of eggs / plant)**

Treatment	15 DAS	22 DAS	29 DAS	36 DAS	43 DAS	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
<b>Neem</b>	2.1625 [1.4705]	0.35 [0.3669]	0.325 [0.5700]	0.7875 [0.8872]	1.1375 [1.0662]	1.7125 [1.3083]	0.6625 [0.5284]	1.4125 [1.1853]	0.1875 [0.4529]	1.55 [1.2447]	0.6125 [0.1116]	0 [0.2256]	0 [0.2256]
<b>HNPV</b>	2.3125	0.55	0.4125	0.8875	1.4375	2.06	1	1.05	0.3	1.8625	0.0375	0.1	0.0375
	[1.5207]	[0.5914]	[0.6421]	[0.9416]	[1.1986]	[1.4314]	[1.22]	[1.0243]	[0.5475]	[1.3646]	[0.1934]	[0.3872]	[0.4742]
<b>Bird perches</b>	2.3	0.575	0.475	0.85	1.85	2.5	1.6625	1.5125	0.325	1.825	0.0375	0.0875	0.0375
	[1.5165]	[0.5913]	[0.6858]	[0.9217]	[1.3600]	[1.5811]	[1.0305]	[1.2297]	[0.5700]	[1.3507]	[0.1935]	[0.3708]	[0.4741]
<b>Endosulfan</b>	2.1875	0.425	0.3625	0.9375	1.65	2.8	0.8125	1.5125	0.2575	1.7375	0.0125	0.0375	0
	[1.4788]	[0.4741]	[0.5229]	[0.9681]	[1.2842]	[1.6730]	[0.9012]	[1.2559]	[0.5359]	[1.3188]	[0.1117]	[0.4743]	[0.2256]
<b>IPM</b>	2.175	0.3625	0.25	0.7375	1.425	1.9125	0.75	1.525	0.1575	1.5125	0.025	0.025	0
	[1.4742]	[0.4028]	[0.50]	[0.6565]	[1.1935]	[1.3625]	[0.6658]	[1.2545]	[0.4529]	[1.2297]	[0.1579]	[0.2738]	[0.2256]
<b>Control</b>	2.2125	0.675	0.625	1.3625	2.2125	3.3625	1.075	1.6625	0.4575	2.0375	0.6375	0.1375	0.05
	[1.4871]	[0.6889]	[0.7933]	[1.1671]	[1.4571]	[3.6322]	[1.0365]	[1.4533]	[0.6351]	[1.0163]	[0.2557]	[0.4330]	[0.3162]
<b>Sed</b>	0.069	0.072	0.031	0.14	0.108	0.107	0.084	0.048	0.22	0.057	0.057	0.046	0.047
<b>CD</b>	0.184	0.151	0.166	0.29	0.227	0.225	0.176	0.101	0.277	0.121	0.141	0.101	0.09

**Appendix I: Efficacy of different treatments against small sized larvae of *H. armigera* during rabi 1998-99 (No. of larvae / plant)**

Treatment	15 DAS	22 DAS	29 DAS	36 DAS	43 DAS	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
<b>Neem</b>	0.275 [0.5244]	2.05 [1.4317]	1.0375 [1.0165]	0.7525 [0.6702]	0.8625 [0.9283]	0.975 [0.9869]	1.9375 [1.4392]	1.3375 [1.1562]	0.925 [0.9609]	1.1125 [1.0541]	1.8 [1.3412]	1.65 [1.2841]	0.2875 [0.5359]
<b>HMPV</b>	0.30 [0.5477]	1.9375 [1.3919]	0.75 [0.8660]	0.8125 [0.9001]	0.85 [0.9213]	1.025 [1.0119]	1.525 [1.3501]	1.2875 [1.1341]	0.9125 [0.9547]	1.05 [1.0242]	1.725 [1.3129]	1.5125 [1.2292]	0.3875 [0.6221]
<b>Bird perches</b>	0.275 [0.5244]	1.875 [1.3693]	1.15 [1.0723]	0.6375 [0.9149]	1.125 [1.0601]	1.4375 [1.1982]	2.525 [1.8700]	1.45 [1.2038]	1.05 [1.0241]	1.3125 [1.1451]	1.625 [1.2742]	1.65 [1.2839]	0.35 [0.5911]
<b>Endosulfan</b>	0.3125 [0.5590]	1.50 [1.2247]	0.7525 [0.8732]	0.725 [0.5501]	0.6375 [0.7979]	0.9125 [0.9546]	1.5375 [1.6731]	1.2125 [1.1636]	0.9875 [0.9932]	1.0375 [1.0167]	1.825 [1.3503]	1.525 [1.2343]	0.35 [0.5908]
<b>IPM</b>	0.325 [0.5701]	2.025 [1.4230]	0.95 [0.9746]	0.7425 [0.5436]	0.775 [0.8800]	0.8875 [0.9477]	1.7525 [1.3259]	1.225 [1.1659]	0.8875 [0.9416]	1.0875 [1.0421]	1.5125 [1.2232]	1.3125 [1.1452]	0.225 [0.4741]
<b>Control</b>	0.3125 [0.5590]	2.10 [1.4491]	1.3675 [1.1779]	1.1125 [0.8541]	1.275 [1.1257]	1.475 [1.2141]	2.5375 [1.8591]	1.5225 [1.2357]	1.0525 [1.0302]	1.40 [1.1627]	2.0125 [1.4179]	1.9 [1.3791]	0.60 [0.7741]
<b>Sed</b>	0.019	0.023	0.019	0.056	0.023	0.06	0.046	0.023	0.014	0.019	0.049	0.023	0.019
<b>CD</b>	0.14	0.21	0.129	0.139	0.029	0.199	0.133	0.12	0.101	0.15	0.21	0.12	0.06

**Appendix III : Efficacy of different treatments against medium sized larvae of *H. armigera* during rabi 1998-99 (No. of larvae / plant)**

Treatment	15 DAS	22 DAS	29 DAS	36 DAS	43 DAS	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Neem	0.0125	0.3000	0.9250	0.2750	0.4000	0.3750	1.0375	0.4500	1.4375	0.4375	0.5250	1.0125	0.3375
	[0.1117]	[0.5470]	[0.9615]	[0.5241]	[0.6321]	[0.6121]	[1.0184]	[0.7738]	[1.1986]	[0.6611]	[0.9050]	[1.0061]	[0.5800]
HMPPV	0.0375	0.3625	0.9375	0.2575	0.3875	0.3750	1.0125	0.4225	1.3750	0.3375	0.7575	0.975	0.1875
	[0.1935]	[0.6019]	[0.9681]	[0.5359]	[0.6222]	[0.6122]	[1.0060]	[0.5500]	[1.1724]	[0.5607]	[0.6673]	[0.9873]	[0.4329]
Bird perches	0.025	0.375	1.175	0.4125	0.5125	0.65	1.05	0.55	1.15	0.475	0.6125	0.95	0.2625
	[0.1590]	[0.6121]	[1.0838]	[0.5420]	[0.7156]	[0.7415]	[1.0244]	[0.7714]	[1.0721]	[0.5690]	[0.9011]	[0.9744]	[0.5122]
Endosulfan	0.05	0.5125	0.9125	0.5375	0.3875	0.45	0.9625	0.50	1.4525	0.3525	0.5375	0.90	0.325
	[0.2234]	[0.5292]	[0.9550]	[0.5613]	[0.6223]	[0.6706]	[0.9909]	[0.7700]	[1.2091]	[0.6018]	[0.9149]	[0.9485]	[0.5659]
IPM	0.052	0.6	0.9875	0.2375	0.375	0.3625	0.6575	0.4575	1.2125	0.4575	0.625	0.5125	0.175
	[0.2457]	[0.5687]	[0.9934]	[0.5358]	[0.6120]	[0.6018]	[0.9417]	[0.6659]	[1.1029]	[0.4529]	[0.7554]	[0.9012]	[0.4180]
Control	0.05	0.7375	1.325	0.475	0.625	0.6875	1.5525	0.4125	1.45	0.5625	0.99	1.2875	0.45
	[0.2235]	[0.5125]	[1.1508]	[0.5680]	[0.7904]	[0.6290]	[1.1670]	[0.7354]	[1.2039]	[0.75]	[0.9048]	[1.1345]	[0.6525]
Sed	0.033	0.023	0.015	0.019	0.029	0.025	0.011	0.015	0.050	0.019	0.014	0.009	0.019
CD	0.174	0.051	0.032	0.042	0.061	0.052	0.023	0.034	0.127	0.029	0.072	0.021	0.042

Appendix IV : Efficacy of different treatments against large sized larvae of *H. armigera* during rabi 1998-99 (No. of larvae / plant)

Treatment	15 DAS	22 DAS	29 DAS	36 DAS	43 DAS	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Neem	0	0.05	0.175	0.075	0.175	0.0875	0.0875	0.175	0.075	0.175	0.375	0.075	0.025
		[0.2236]	[0.4181]	[0.2737]	[0.4182]	[0.2957]	[0.2957]	[0.4182]	[0.2736]	[0.4181]	[0.6121]	[0.2737]	[0.1580]
HINPV	0	0.025	0.2125	0.0675	0.15	0.125	0.0625	0.2	0.625	0.125	0.25	0.1	0.0125
		[0.1581]	[0.4607]	[0.2956]	[0.3871]	[0.3534]	[0.25]	[0.4472]	[0.25]	[0.3534]	[0.5]	[0.3161]	[0.1117]
Bird perches	0	0.075	0.2625	0.125	0.0875	0.1125	0.0875	0.2125	0.0625	0.1125	0.3875	0.1	0.0625
		[0.2737]	[0.5122]	[0.3534]	[0.2956]	[0.3532]	[0.2956]	[0.4607]	[0.2688]	[0.3533]	[0.6223]	[0.3162]	[0.25]
Endosulfan	0	0.025	0.2	0.05	0.1	0.1125	0.05	0.125	0.075	0.1	0.325	0.075	0.05
		[0.1579]	[0.4471]	[0.2235]	[0.3160]	[0.3533]	[0.2235]	[0.3535]	[0.2738]	[0.3161]	[0.5700]	[0.2737]	[0.2235]
IPM	0	0.875	0.2125	0.075	0.1125	0.125	0.0625	0.065	0.05	0.375	0.25	0.1	0.025
		[0.1535]	[0.4638]	[0.2735]	[0.3353]	[0.3534]	[0.25]	[0.2548]	[0.2235]	[0.3707]	[0.4998]	[0.3160]	[0.1580]
Control	0	0.1875	0.35	0.175	0.3525	0.2525	0.2575	0.33	0.125	0.35	0.6	0.25	0.125
		[0.4300]	[0.5975]	[0.4181]	[0.6019]	[0.5122]	[0.4572]	[0.5700]	[0.3535]	[0.5516]	[0.7745]	[0.5307]	[0.3534]
Sed	0.016	0.029	0.03	0.052	0.058	0.014	0.048	0.024	0.108	0.18	0.024	0.038	0.043
CD	0.180	0.062	0.05	0.053	0.121	0.03	0.101	0.051	0.227	0.039	0.051	0.025	0.051

Appendix V : Efficacy of different treatments against all sized larvae of *H. armigera* during rabi 1998-99 (No. of larvae / plant)

Treatment	15 DAS	22 DAS	29 DAS	36 DAS	43 DAS	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Neem	0.2875	2.4	2.1375	1.1125	1.4375	1.4375	3.2	1.6525	2.5375	1.925	2.7	2.6875	0.7125
	[0.5362]	[1.5492]	[1.462]	[1.0547]	[1.1959]	[1.1989]	[1.7888]	[1.3547]	[1.5929]	[1.3874]	[1.6431]	[1.6393]	[0.8444]
HNPV	0.3375	2.325	1.9	1.1875	1.3875	1.525	3.0375	1.8125	2.4125	1.5375	2.6125	2.5	0.6375
	[0.5809]	[1.5247]	[1.3784]	[1.0897]	[1.1779]	[1.2349]	[1.7428]	[1.3463]	[1.5532]	[1.2796]	[1.6163]	[1.5811]	[0.7554]
Bird perches	0.3	2.325	2.5875	1.375	1.725	2.1	3.8875	2.0525	2.3125	2.175	2.5375	2.6625	0.7
	[0.5477]	[1.5248]	[1.6085]	[1.1726]	[1.3134]	[1.4491]	[1.9716]	[1.4361]	[1.5207]	[1.4747]	[1.5929]	[1.6317]	[0.8555]
Endosulfan	0.3625	1.8	1.875	1.2125	1.125	1.475	2.975	1.7575	2.55	1.725	2.7375	2.475	0.725
	[0.6021]	[1.3416]	[1.3693]	[1.1011]	[1.1011]	[1.2144]	[1.7248]	[1.3359]	[1.5968]	[1.3134]	[1.6545]	[1.5732]	[0.6544]
IPM	0.387	3.2125	2.15	1.075	1.2625	1.375	2.715	1.7525	2.2375	1.525	2.2375	2.15	0.4525
	[0.6221]	[1.7923]	[1.4662]	[1.0388]	[1.1236]	[1.1726]	[1.6477]	[1.3276]	[1.4958]	[1.2349]	[1.4658]	[1.4563]	[0.6554]
Control	0.3625	2.8	3.0625	1.7625	2.2525	2.425	4.375	2.2	2.8525	1.5525	3.2525	3.3125	1.2375
	[0.6021]	[1.6735]	[1.75]	[1.3275]	[1.5541]	[1.5572]	[2.0916]	[1.4532]	[1.6518]	[1.6337]	[1.8034]	[1.6201]	[1.1124]
Sed	0.015	0.025	0.019	0.058	0.033	0.03	0.046	0.033	0.014	0.019	0.045	0.033	0.019
CD	0.14	0.21	0.129	0.129	0.129	0.199	0.199	0.14	0.199	0.14	0.21	0.199	0.14



Appendix.VII : Efficacy of different treatments against small size larvae of *H. armigera* during rabi 1999-2000 (No. of larvae / plant)

Treatment	24 DAS	33 DAS	40 DAS	45 DAS	47 DAS	54 DAS	66 DAS	68 DAS	75 DAS	81 DAS	83 DAS	90 DAS	97 DAS	98 DAS	105 DAS	112 DAS
Neem	0.45	0.5375	0.586	0.7125	0.65	0.9625	1.413	1.325	0.625	0.6125	0.625	0.4375	0.7875	0.725	0.375	0.2625
	[0.6707]	[0.7331]	[0.7415]	[0.8439]	[0.8062]	[0.9809]	[1.1883]	[1.1509]	[0.7904]	[0.7825]	[0.9905]	[0.6612]	[0.8871]	[0.8513]	[0.6121]	[0.5121]
HNPV	0.48	0.5125	0.4375	0.6125	0.63	0.900	1.375	1.35	0.5625	0.63	0.6	0.39	0.7	0.775	0.3375	0.25
	[0.6827]	[0.7157]	[0.6613]	[0.7825]	[0.7904]	[0.9485]	[1.1725]	[1.1617]	[0.75]	[0.7904]	[0.7744]	[0.62247]	[0.8364]	[0.8801]	[0.5806]	[0.50]
Bird perches	0.55	0.7625	1.1375	0.81	0.8000	1.713	1.3750	1.2875	0.9875	0.7625	0.8125	0.9875	0.7875	0.8875	0.8125	0.6875
	[0.7415]	[0.8731]	[1.0665]	[0.9012]	[0.8943]	[1.3085]	[1.1726]	[1.1344]	[0.9936]	[0.8731]	[0.9011]	[0.9935]	[0.8872]	[0.9417]	[0.9012]	[0.8289]
Endosulfan	0.5	0.2875	0.3875	0.725	0.238	1.125	1.4	0.6375	0.9125	0.675	0.475	0.6375	8375	0.425	0.4625	0.3625
	[0.7071]	[0.5360]	[0.6223]	[0.8513]	[0.4872]	[1.0604]	[1.1831]	[0.7983]	[0.9551]	[0.8214]	[0.6890]	[0.7982]	[0.9150]	[0.6518]	[0.6800]	[0.6017]
IPM	0.525	0.4875	0.49	0.70	0.6	0.925	1.325	0.525	0.85	0.6375	0.6125	0.4625	0.6625	0.625	0.25	0.2
	[0.7243]	[0.6981]	[0.6981]	[0.8365]	[0.7744]	[0.9616]	[1.1509]	[0.7244]	[0.9217]	[0.7982]	[0.7823]	[0.6800]	[0.8138]	[0.7502]	[0.50]	[0.4470]
Control	0.475	0.788	1.175	0.825	0.7750	1.7625	1.463	1.3750	1.0375	0.7875	0.850	1.075	0.8875	0.91	0.9	0.8875
	[0.6891]	[0.8873]	[1.0837]	[0.9081]	[0.8802]	[1.3273]	[1.2091]	[1.1725]	[1.0184]	[0.8874]	[0.9217]	[1.0368]	[0.9419]	[0.9550]	[0.9483]	[0.9419]
Sed	0.048	0.042	0.038	0.048	0.033	0.019	0.019	0.023	0.014	0.033	0.048	0.033	0.023	0.028	0.023	0.042
CD	0.101	0.091	0.082	0.101	0.071	0.041	0.042	0.053	0.032	0.071	0.101	0.072	0.051	0.063	0.052	0.09



Appendix VIII: Efficacy of different treatments against medium size larvae of *H. armigera* during rabi 1999-2000 (No. of larvae / plant)

Treatment	24 DAS	33 DAS	40 DAS	45 DAS	47 DAS	54 DAS	66 DAS	68 DAS	75 DAS	81 DAS	83 DAS	90 DAS	97 DAS	98 DAS	105 DAS	112 DAS
Neem	0	0.4625	0.2	0.425	0.2875	0.213	0.375	0.475	0.5625	0.3875	0.9875	0.4525	0.4525	0.3375	0.2625	0.2125
	[0.2236]	[0.6800]	[0.4471]	[0.6518]	[0.5360]	[0.4607]	[0.6122]	[0.6852]	[0.75]	[0.6223]	[0.9936]	[0.5530]	[0.5739]	[0.5808]	[0.5122]	[0.4698]
HNPV	0	0.4625	0.1375	0.3875	0.275	0.1625	0.2375	0.6125	0.325	0.38	0.9375	0.45	0.3675	0.2625	0.2215	0.175
	[0.2236]	[0.6798]	[0.4471]	[0.6222]	[0.5245]	[0.4030]	[0.4972]	[0.7825]	[0.5700]	[0.6123]	[0.9681]	[0.5518]	[0.6222]	[0.5122]	[0.4742]	[0.4182]
ird perche	0	0.5375	0.3875	0.725	0.4875	0.4375	0.5125	0.9375	0.8875	0.775	1.3125	0.5125	1.0625	0.825	0.5715	0.4875
	[0.2236]	[0.7350]	[0.6224]	[0.8513]	[0.6881]	[0.6614]	[0.7157]	[0.9552]	[0.9419]	[0.8802]	[1.1455]	[0.5070]	[0.606]	[0.9081]	[0.7580]	[0.6981]
Endosulf	0	0.275	0.2875	0.5875	0.1125	0.225	0.425	0.3625	0.4875	0.9875	0.825	0.5375	0.5625	0.5125	0.525	0.375
	[0.2236]	[0.5243]	[0.5360]	[0.7661]	[0.3353]	[0.4742]	[0.5517]	[0.6045]	[0.6980]	[0.9935]	[0.9081]	[0.7552]	[0.7250]	[0.7150]	[0.7244]	[0.6120]
IPM	0	0.4	0.19	0.44	0.2825	0.13	0.2	0.7625	0.4875	0.7125	0.6125	0.4375	0.3625	0.2375	0.213	0.125
	[0.2236]	[0.6322]	[0.4328]	[0.6631]	[0.5121]	[0.3538]	[0.4470]	[0.8750]	[0.6979]	[0.8440]	[0.7824]	[0.5573]	[0.5079]	[0.1870]	[0.4607]	[0.3533]
Control	0	0.6125	0.4625	0.625	0.5825	0.725	0.810	1.275	1.113	1.025	1.4875	0.425	0.4375	0.875	0.675	0.5375
	[0.2236]	[0.7625]	[0.6800]	[0.8000]	[0.7631]	[0.8513]	[0.9343]	[1.1250]	[1.0646]	[1.0123]	[1.2156]	[0.5050]	[0.5554]	[0.9353]	[0.8214]	[0.7330]
Sed	0	0.019	0.023	0.019	0.058	0.023	0.05	0.045	0.023	0.014	0.019	0.045	0.025	0.019	0.014	0.019
CD	0.00	0.04	0.05	0.040	0.12	0.050	0.027	0.10	0.05	0.03	0.04	0.03	0.04	0.04	0.03	0.04

**Appendix IX: Efficacy of different treatments against large size larvae of *H. armigera* during rabi 1999-2000 (No. of larvae / plant)**

Treatment	24 DAS	33 DAS	40 DAS	45 DAS	47 DAS	54 DAS	66 DAS	75 DAS	81 DAS	83 DAS	90 DAS	97 DAS	98 DAS	105 DAS	112 DAS	
<b>Neem</b>	0	0	0.1125	0.0625	0.075	0	0	0.25	0.525	0.1	0.2	0.46	0.075	0.375	0.025	0.05
	[0.2236]	[0.2236]	[0.3353]	[0.2498]	[0.2737]	[0.1580]	[0.2236]	[0.5]	[0.7243]	[0.3161]	[0.4028]	[0.6760]	[0.2737]	[0.1935]	[0.2737]	[0.3161]
<b>HNPV</b>	0	0	0.075	0.025	0.05	0.0125	0	0.2625	0.4375	0.088	0.175	0.3800	0.0375	0.0375	0.0375	0.05
	[0.2236]	[0.2236]	[0.2737]	[0.1580]	[0.2234]	[0.1117]	[0.2236]	[0.5122]	[0.6612]	[0.2957]	[0.4181]	[0.6202]	[0.1933]	[0.1934]	[0.2957]	[0.3161]
<b>Bird perches</b>	0	0.0375	0.0375	0.0375	0.0625	0.05	0.1125	0.2125	0.5125	0.1	0.2	0.39	0.0375	0.0375	0.075	0.0625
	[0.2236]	[0.1935]	[0.1936]	[0.1935]	[0.2497]	[0.2236]	[0.4030]	[0.4607]	[0.7156]	[0.3162]	[0.4470]	[0.6301]	[0.1935]	[0.1936]	[0.3534]	[0.3353]
<b>Endosulfan</b>	0	0	0.0625	0.125	0.0125	0.0375	0.1375	0.15	0.5375	0.1625	0.0875	0.41	0.1375	0.025	0.025	0.125
	[0.2236]	[0.2236]	[0.25]	[0.3532]	[0.3533]	[0.1934]	[0.4329]	[0.3870]	[0.7329]	[0.4029]	[0.2956]	[0.6401]	[0.3706]	[0.1580]	[0.2736]	[0.4182]
<b>IPM</b>	0	0	0.13	0.05	0.1	0.05	0.025	0.1375	0.45	0.1375	0.175	0.3975	0.0625	0.025	0	0
	[0.2236]	[0.2236]	[0.4182]	[0.3352]	[0.4030]	[0.4608]	[0.2737]	[0.6323]	[0.6706]	[0.4329]	[0.5242]	[0.6302]	[0.4329]	[0.2957]	[0.2236]	[0.2236]
<b>Control</b>	0	0	0.175	0.1125	0.1625	0.2125	0.24	0.4	0.55	0.1875	0.275	0.575	0.1875	0.1	0.1	0.1625
	[0.2236]	[0.2236]	[0.4182]	[0.3350]	[0.4029]	[0.4607]	[0.5360]	[0.6322]	[0.7413]	[0.4327]	[0.5241]	[0.7580]	[0.4328]	[0.2956]	[0.3871]	[0.4608]
<b>Sed</b>	0	0.004	0.015	0.014	0.09	0.014	0.025	0.057	0.009	0.019	0.057	0.56	0.028	0.043	0.014	0.019
<b>CD</b>	0	0.01	0.04	0.03	0.04	0.03	0.06	0.121	0.02	0.04	0.101	0.121	0.06	0.09	0.03	0.04

**Appendix X: Efficacy of different treatments against all size larvae of *H. armigera* during rabi 1999-2000**

Treatment	24 DAS	33 DAS	40 DAS	45 DAS	47 DAS	54 DAS	60 DAS	68 DAS	75 DAS	81 DAS	83 DAS	90 DAS	97 DAS	98 DAS	105 DAS	112 DAS
Neem	1.0 [1.0]	0.625 [0.9287]	1.2 [1.0552]	1.0125 [1.0062]	1.2 [1.095]	1.7875 [1.3369]	2.05 [1.4317]	1.7125 [1.3084]	1.1 [1.0468]	1.775 [1.3523]	1.4 [1.1659]	1.25 [1.1511]	1.1 [1.0488]	0.6625 [0.8139]	0.525 [0.7245]	0.525 [0.7245]
HNPV	0.975 [0.9674]	0.65 [0.8062]	1.025 [1.0122]	0.95 [0.9745]	1.075 [1.0668]	1.6125 [1.2698]	2.225 [1.4916]	1.325 [1.1508]	1.0875 [1.0428]	1.713 [1.3056]	1.1975 [1.0941]	1.125 [1.0806]	1.075 [1.0368]	0.6 [0.7745]	0.475 [0.6892]	0.475 [0.6892]
Bird perches	1.3975 [1.1569]	1.5825 [1.29]	1.575 [1.2548]	1.35 [1.1618]	2.2 [1.4832]	2.0 [1.4142]	2.4375 [1.5612]	2.3875 [1.5450]	1.6375 [1.2798]	2.325 [1.5247]	2.1975 [1.4820]	1.8875 [1.3738]	1.75 [1.3228]	1.4825 [1.2053]	1.2375 [1.1124]	1.2375 [1.1122]
Endosulfan	0.5825 [0.79]	0.7375 [0.6588]	1.4375 [1.1997]	0.3625 [0.6021]	1.3875 [1.1779]	1.9825 [1.4009]	1.15 [1.0724]	1.9375 [1.3917]	1.825 [1.3509]	1.3875 [1.7779]	1.685 [1.2978]	1.6375 [1.3555]	0.9825 [0.9811]	1.0125 [1.0062]	0.8825 [0.9287]	0.6825 [0.9255]
IPM	0.8875 [0.9421]	0.8 [0.8944]	1.1875 [1.0895]	0.9825 [0.9811]	1.1 [1.0488]	1.57 [1.2449]	1.425 [1.1937]	1.7875 [1.3366]	1.6875 [1.2196]	1.4 [1.1832]	1.2975 [1.1387]	1.0375 [0.928]	0.8875 [0.9421]	0.4625 [0.8801]	0.325 [0.5701]	0.325 [0.5701]
Control	1.4 [1.1832]	1.8125 [1.3463]	1.7375 [1.3180]	1.58 [1.2568]	2.7 [1.6331]	2.5125 [1.5851]	3.05 [1.7464]	2.7 [1.6429]	2.0 [1.4142]	2.6125 [1.6163]	2.7 [1.6306]	2.2125 [1.4374]	1.875 [1.3693]	1.675 [1.2942]	1.5875 [1.2599]	1.5875 [1.257]
Std	0.019	0.048	0.023	0.014	0.033	0.025	0.023	0.042	0.033	0.015	0.036	0.023	0.06	0.015	0.029	0.019
CD	0.041	0.101	0.053	0.032	0.071	0.063	0.052	0.091	0.071	0.042	0.082	0.052	0.127	0.042	0.061	0.042