MICROBIAL MANAGEMENT OF *Helicoverpa armigera* (Hubner) ON CHICKPEA

THESIS

Submitted to the
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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BY
SAMEER NARENDRA KALE

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY,
POST GRADUATE INSTITUTE,

Dr. PANJABRAO DESHMUKH KRISHI VIDYAPEETH,
AKOLA (M.S.) INDIA

Enrolment No. U / 79 2006

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled **"MICROBIAL MANAGEMENT OF *Helicoverpa armigera* (Hubner) ON CHICKPEA"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publications of any University or Scientific Organization. The source of materials used and all the assistance received during the course of investigation have been duly acknowledged.

Place : Akola

Date : 31 / 05 /2006

(S.N. Kale)

Enrolment No. U / 79

CERTIFICATE

This is to certify that the thesis entitled **"MICROBIAL MANAGEMENT OF *Helicoverpa armigera* (Hubner) ON CHICKPEA"** submitted in partial fulfillment of the requirement for the degree of **"DOCTOR OF PHILOSOPHY IN AGRICULTURAL ENTOMOLOGY"** of the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, is a record of bonafide research work carried out by **Mr. Sameer Narendra Kale** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

(U.B. Men)
Chairman
Advisory Committee.

Countersigned

Associate Dean,
Post Graduate Institute,
Dr. PDKV, Akola.

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL MEMBER. (AFTER VIVA-VOCE)

1. (Chairman)	Dr. U.B. Men	
2. (Member)	Prof. M.N. Nachane	
3. (Member)	Dr. S.D. Desmukh	
4. (Member)	Dr. S.R. Katole	
5. (Member)	Dr. B.T. Raut	
6. (External Member)	(Dr. P. R. Shivpuje)	

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Place : Akola

Date : 31/05/2006

(S.N. Kale)

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ABRIVATIONS USED

%	:	Per cent
/	:	Per
@	:	at the rate of
a.i.	:	Active ingradient
Bt	:	*Bacillus thuri ngiensis*
C.D.	:	Critical Difference
C.V.	:	Coefficient of variations
cm	:	Centimetre
EC	:	Emulsifiable concentrate
et al.	:	*et alia* (and his associates)
etc	:	et cet era
g	:	Gram (s)
ha	:	Hectare
HaNPV	:	*Helicoverpa armigera* nuclear polyhedrosis virus
H. armigera	:	*Helicoverpa armigera*
hr	:	Hour(s)
i.e.	:	id est (that is)
ICBR	:	Incremental cost benefit ratio
IU	:	International Unit
kg	:	Kilogram

LE	:	Larval Equivalent
lit.	:	Litre
m	:	Metre (s)
Max.	:	Maximum
Met. week	:	Meteorological week
Min.	:	Minimum
ml	:	Militre (s)
No.	:	Number
NSKE	:	Neem seed kernel extract
°C	:	Degree centigrade
PIBs	:	Polyhedral inclusion bodies
POB	:	Polyhedral occlusion bodies
q	:	Quintal(s)
RH	:	Relative humidity
Rs.	:	Rupees
S.E.(m)±	:	Standard error of Means
SC	:	Soluble concentrate
Sig.	:	Significant
sp	:	Species
t	:	Tonnes
viz.,	:	Videlict (namely)

CHAPTER – I

INTRODUCTION

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INTRODUCTION

In spite of being the largest producer in the world, India has to import pulses to the tune of 2 million tonnes every year to meet its domestic requirement. This is due to the fact that pulses are inseparable ingredient of vegetarian diet and one of the cheapest source of dietary protein in the country. On the other hand per capita availability of pulses has decreased from 69 g in 1961 to 37 g in 2004, which is below than recommended 50 g pulses/capita/day, causing protein malnutrition in the country (Ali and Shivkumar, 2005)

Like any other pulses, supplementation of chickpea with cereal-based diets is considered one of the possible solutions to the problem associated with protein energy malnutrition. The daily per capita availability of 14 g chickpea is a source of approximately 2.3 % (56 K Cal.) energy and 4.7 % (2.7 g) protein to Indian population besides being a major source of calcium, iron and phosphorus (Ali and Shivkumar, 2003)

Cultivation of Chickpea (*Cicer arietinum* L.) was started in 2300 BC (Reddy and Reddy, 1997) and then it occupied prominent place amongst pulses and is gaining increasing popularity day by day because of it's high nutritional value, low cost of cultivation, capacity to withstand water-stress condition, and ability to add nitrogen in the soil. It adds upto 108 kg nitrogen per hectare, thus can be suitably included in cropping system (Baldev *et al*., 1988).

Worldwide, chickpea is cultivated on 9.94 million hectares area with production of 7.85 million tones. However, India's share in its cultivation and production is 61.31 % and 67.07 %, respectively (Anonymous, 2003 a). In

Maharashtra, it is cultivated over an area of 7.56 million hectares with the production of 7.70 million tones, while in Vidarbha it is cultivated on 1.94 lakh hectares area with production of 5.07 lakh tones (Anonymous, 2005).

Chickpea is reported to be attacked by about 57 insect pests amongst which gram pod borer *Helicoverpa armigera* is the only major pest (Sarode and Sarnaik, 1996). The investigation carried out at ICRISAT indicated that the pest complex of chickpea is the limiting factor in its profitable cultivation causing average damage to the extent of 29.21 %. However damage to chickpea by *H. armigera* alone varied both in space and time and the extent of damage has been 10 per cent to 90 per cent with a crop damage of 20 per cent is not uncommon (Sing *et al.*, 1983). In Maharashtra state about half a dozen of insect species are found to feed on chickpea. Since last 2 ½ decades an increase in cultivation of hybrids of crops like cotton, jowar, sunflower etc. under irrigation has increased the availability of alternate and preferred hosts leading to increase in the population of *H. armigera* (Mahajan *et al.*, 1990).

Several chemical insecticides have been found effective against this pest. However, due to overuse and misuse of these chemical insecticides natural balance has been disturbed leading to enormous problems such as resistance, residues, resurgence, destruction of natural enemies, pollution, health hazards etc. This enforced researchers to manage this pest by alternate, effective and eco-friendly biological methods.

Microbial control is the eco-friendly method of insect pest control and is gaining increasing popularity because of its effectiveness. It refers to the exploitation of disease causing organisms to reduce the population of insect-pests below the damaging levels. So far over 3000 microorganisms have been reported to cause diseases in insects (Dhaliwal and Arora, 2001). Insecticides containing disease causing microorganisms as an active ingredient for the control of insect-pests is called as microbial insecticides. Some microbial insecticides containing virus (*Helicoverpa armigera* nuclear polyhedrosis virus), Bacteria (*Bacillus thuringiensis*) and fungus (*Metarhizium anisopliae, Beauveria bassiana*) are found effective in controlling *Helicoverpa armigera* in Chickpea ecosystem. (Pharindera Yadav *et al.*, 2004; Musa and Johansen, 2003 and Ramteke *et al*, 2002). However, efficacy of such microbial insecticides in combination or in schedule application has not been fully exploited. Therefore in the present investigation efforts have been made to test some microbial insecticides either alone or in combination and their schedule application for the control of *Helicoverpa armigera* in Chickpea ecosystem. Beside this, basic studies on biotic complex, population dynamics and effect of malic acid on larval and pupal development of *Helicoverpa armigera* have been undertaken.

CHAPTER – II

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

The critical review from the available literature as regards various aspects of the present investigations was made and presented below.

2.1 Evaluation of microbial pesticides either alone or in combination

2.1.1 Efficacy of fungal pathogens against *H. armigera*

During the studies on the compartive performance of indigenous fungal isolates i.e. *Metarhizium anisopliae* M 34412, *Beauveria bassiana* B 3301 and *Nomuraea rileyi* N 812 for the control of *Helicoverpa armigera* on chickpea under field conditions Pallavi Nahar *et al.* (2003) reported that all the treatments gave 50-80 per cent reduction in the *H. armigera* population as compared to the control. The per cent efficacy for *Metarhizium anisopliae* M 34412 was 80 % while for *Bacillus thuringiensis* B 3301 was 52 % and *Nomuraea rileyi* N 812 was 61 %. They also reported highest grain yield of 16.64 q / ha from *Metarhizium anisopliae* followed by endosulfan (15 q / ha) and HaNPV (14.28 q / ha). The yield from *Beauveria bassiana* treated plot was 11.9 q / ha.

Dhembare and Siddique (2004) evaluated formulation of mycoinsecticide, *Beauveria bassiana* in the laboratory against gram pod borer *H. armigera* during 2001-02. They observed maximum reduction at 72 hrs post-treatment when larva and food treated together. They also reported that Ist and IInd instar larvae were more susceptible to *Beauveria bassiana* than other instars.

Phadtare *et al.* (2004) studied the compatibility of the entomogenous fungus *Beauveria bassiana* with chemical and microbial pesticides against *Helicoverpa armigera*. They reported that *Beauveria bassiana* was less effective than HaNPV, Bt or their combinations with *Beauveria bassiana* at full doses.

Pharindera Yadav *et al.* (2004) tested the efficacy at bio-pesticides against *H. armigera* on chickpea. They found that *Beauveria bassiana* @ 1 kg / ha reduced the larval population from 2.63 per plant to 2.22, 1.54 and 1.43 per plant at 3,7 and 14 days after sprayings.

Shivramkrishna (2004) tested performance of different microbials against *Helicoverpa armigera* on chickpea. They reported that *Metarhizium anisopliae* @ 10^{10} spores / ml causes 58.30 and 60.33 per cent reduction in larval population at 7 and 14 days after spraying. They also reported higher grain yield and more cost benefit ratio from *Metarhizium anisopliae* than *Beauveria bassiana*.

Field evaluation of *Metarhizium anisopliae* against *Helicoverpa armigera* on pigeonpea was carried out by Undirwade *et al.* (2004). They reported that *Metarhizium anisopliae* at 10^8 conidia / ml was equally effective with HaNPV @ 250 LE / ha and Bt @ 1000 g / ha in reducing larval population, pod damage and also produced equal grain yield. The cost benefit ratio was more in HaNPV (1 : 22.95) than *Metarhizium anisopliae* (1 : 17.13), while it was least (1: 6.16) for *Bacillus thuringiensis*.

Kulkarni *et al.* (2005) tested efficacy of *Beauveria bassiana* and *Nomuraea rileyi* at 0.5, 1.0 and 1.5 g / lit against *H. armigera* in chickpea. They reported that both the fungal pathogens were effective in reducing larval population at 3, 7 and 15 days after spraying and also produced significantly higher grain yield than untreated control but were proved less efficacious over chemical insecticides. Further they also studied the performance of HaNPV against *H. armigera* on chickpea, and reported that *Metarhizium anisopliae* @ 2 g / lit has effectively reduced the larval population up to 23.33 , 38.50 and 43.88 per cent at 5,7 and 15 days after spraying and produced significantly higher grain yield (7.42 q / ha) than untreated control.

The effectiveness of oil-based conidia formulations of indigenous fungal isolates *Metarhizium anisopliae* M43412, *Beauveria bassiana* B 3301 and *Nomuraea rileyi* N 812 were evaluated against *Helicoverpa armigera* infestation on Pigeonpea under field conditions by Nahar *et al.* (2004). The *Metarhizium anisopliae* conidia in oil formulation were found most effective giving 66.74 ± 11.86 and 75.11 ± 9.48 per cent cumulative efficacy after first and second spraying, respectively. It also produced highest yield of 14.04 q / ha. Whereas, the conidia formulations of *Beauveria bassiana* was less effective giving 51.25 ± 10.37 and 59.77 ± 10.36 per cent cumulative efficacy after first and second spraying and 10.18 q / ha yield of chickpea grains.

Sidde Gowda and Suhas Yelshetty (2005) evaluated some microbial agents against gram pod borer during 1998 and 1999 at Gulbarga. They reported that larval populations were at par in all the treatments at 3 days after first spray and 3 and 7 days after second spray. The highest grain yield (10.26 q / ha) was recorded from HaNPV treated plots whereas *Beauveria bassiana* treated plot recorded 8.36 q / ha grain yield.

Singh and Yadav (2005) tested some microbial agents against *H. armigera* in chickpea field. Results of two years field trials revealed that among microbial control agents tested, *Beauveria bassiana* (1.0 X 10^8 spores / ml) and HaNPV (250 LE / ha) proved more efficacious in reducing the pod damage and enhancing productivity. Both these bio-agents stood only next to endosulfan (0.7 kg / ha). *Metarhizium anisopliae* (1.0 X 10^8 spores / ml) and *Bacillus thuriengiensis* base formulations viz., delfin, biobit and dipel each at 1.0 kg or 1.0 L / ha proved less efficacious than either *Beauveria bassiana* or HaNPV.

Study conducted at college of Agriculture, Nagpur for three years (2003-06) revealed that, *Metarhizium anisopliae* at 10^6, 10^7, 10^8, 10^9 and 10^{10} spores / ml was effective in reducing larval population of *H. armigera* on pigeonpea at 3, 4 and 14 days after spraying. It also recorded significantly higher grain yield than control. But all these concentrations of *Metarhizium anisopliae* were proved less effective than endosulfan (Anonymous, 2006).

2.1.2 Efficacy of nuclear polyhedrosis virus against *H. armigera*

A field trial to investigate the effect of nuclear polyhedrosis virus on *H. armigera* infesting chickpea was carried out by Narayanan (1980). It was noticed by him that application of virus (@ 250 LE and 125 LE / ha) during evening hours thrice at weekly interval after the appearance of early instars, caused significant reduction in the larval population.

Laboratory and pot experiments were carried out by Odak *et al.* (1982) to determine the effectiveness of various formulations of *Bacillus thuringiensis* and cultures of NPV against *Heliothis armigera* (Hb), a pest of chickpea. Of various virus cultures tested, the local Jabalpur and Narsingpur were most effective, causing 66.6 - 72.5 % , mortality in the laboratory and 52.5-93.3 % in the pot experiment.

Santharam and Balasubramanian (1982) found that three sprayings of nuclear polyhedrosis virus at 375 LE / ha gave maximum protection and produced highest grain yield than chemical insecticides sprayed either alone or in combinations with nuclear polyhedrosis virus at reduced doses.

Effectiveness of an indigenous nuclear polyhedrosis virus of *Heliothis* was tested against *H. armigera* infesting chickpea by Anita Mistry *et al.* in 1984 in Gujrat. It was concluded that five sprays applications of the virus @ 250 LE / ha at weekly interval gave satisfactory control of the pest causing 89.80 per cent average mortality of larvae and produced increase gain yield of 28 per cent in 1980-81 and 83.05 per cent mortality as well as 47 per cent increase in yield during 1981-82 over control.

Dhamdhere and Khaire (1986), tested nuclear polyhedrosis virus at 150, 200, 250, 300, 350, 400 and 450 LE / ha against *H. armigera* on *Cicer arietinum* in Maharashtra. Two applications of NPV of *H. armigera* @ 450 LE / ha at a 10 day interval were most effective in reducing damage and resulted in the highest yield.

Field trials were conducted by Jayaraj *et al.* (1987) to evaluate the efficacy of nuclear polyhedrosis virus for the control of *H. armigera* on chickpea. Overall performance revealed that application of nuclear polyhedrosis virus @ 250 LE / ha gave significantly reduced larval count from initial 18.8 to 15.8, 4.0 and 3.0 per ten plants at 5,7 and 10 days after spraying, respectively.

Pawar *et al.* (1987), evaluated HaNPV and endosulfan against pod borer *Heliothis armigera* (Hubner) on chickpea. Two sprays of endosulfan @ 0.05 % applied at 15 days interval reduced per plant larval population from 2.25 to 0.95 and 0.65 and further up to 0.25 and 0.00 at 7 and 14 days after first and second spray, respectively. Where as HaNPV @ 250 LE / ha reduced per plant larval population from 2.65 to 2.40 and 0.85 and further up to 0.55 and 0.20 at 7 and 14 days after first and second spray, respectively. Two sprays of endosulfan also produced highest grain yield of 605 kg / ha where as it was 13.4 kg / ha in treatment with HaNPV.

Pawar *et al.* (1990) had tested efficacy of nuclear polyhedrosis virus against *Heliothis* on gram for three years. The virus was applied at 100, 250 and 500 LE / ha alone or with endosulfan. All the treatments except the lowest concentration of virus alone and with endosulfan, significantly increased grain yield (14-31 %). Highest grain yield (1379 kg / ha) was recorded when plots were treated with two sprays of endosulfan alone or with highest concentration of virus.

Efficacy of endosulfan, herbal products alone and in combination with nuclear polyhedrosis virus against *Heliothis armigera* on gram was tested by Supare *et al.* (1991). They reported that *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha was as effective as endosulfan in reducing per cent larval population 6 days after spraying and produced equal grain yield (18.97 q / ha) as that of endosulfan.

The interaction between chickpea genotypes, endosulfan and nuclear polyhedrosis virus was studied by Bhagwat (1992) and found that *Helicoverpa armigera* nuclear polyhedrosis virus@ 250 LE / ha alone recorded significantly higher per cent larval reduction i.e. 15.72, 47.70 and 68.64 at 3,7 and 15 days after treatment and also higher grain yield (14.54 q / ha) than control.

Sarode *et al.* (1993) had tested effect of various concentrations of nuclear polyhedrosis virus (200, 300, 400 and 500 LE / ha) against *H. armigera* on chickpea. They reported significantly higher grain yield (1.30 to 1.64 t / ha) in all the treatmetns over control (1.00 t / ha). They also reported that two sprays of NPV at 15 days interval were more effective than single spray application.

Field efficacy of *Helicoverpa armigera* nuclear polyhedrosis virus alone and in combination with delfin was tested against *H. armigera* on chickpea in Tamil Nadu, India by Srinivisan *et al.* (1994). After 6 spray application between 30 to 90 days after sowing they found that HaNPV @ 250 LE / ha was statistically superior to endosulfan in reducing larval population in the first two sprays. However, from the 3rd spray onwards all the treatments were on a par with each other. The cost benefit analysis indicated that HaNPV @ 250 LE / ha was the most effective treatment followed by endosulfan.

Sarode *et al.* (1995) studied the performance of *Helicoverpa armigera* nuclear polyhedrosis virus combined with neem seed kernel extract against the pod borer on chickpea. They reported significantly higher grain yield of 1270 kg / ha in the treatment of HaNPV @ 500 LE / ha as against 892 kg / ha in control.

Efficacy of different insecticides against pod borer on chickpea was tested by Datkhile *et al.* (1996) for three year (1989-92). Three sprays of insecticides were applied at 15 days interval. Pooled data of three years revealed that nuclear polyhedrosis virus 250 LE / ha causes 48.6, 56.1 and 52.6 per cent reduction in larval population at 2, 7 and 15 days after treatment, respectively. It also produced 14.0 q / ha yield of chickpea grains and cost benefit ratio of 1:2.6, as against 10.7 q / ha yield in control.

Shukla *et al.* (1996) evaluated nuclear polyhedrosis virus (NPV) for the control of *Heliothis armigera* (Hubner) on chickpea under the agro-ecosystem of Satpura plateau of Madhya Pradesh, India. They reported that nuclear polyhedrosis virus applied at 250, 300 and 350 LE / ha produced significantly higher seed yield (1.26-1.33 t / ha) compared to untreated control plots (1.17 t / ha), but it was lower than plots treated with endosulfan (1.60 t / ha).

Vyas and Lakhchaura (1996) studied effects of nuclear polyhedrosis virus of *Helicoverpa armigera* on pod damage and yield of chickpea at Pantnagar (U.P.). They found that two spray of NPV @ 250 LE / ha produced statistically equal grain yield (770 kg / ha) as that of single spray of endosulfan (769 kg / ha) and were significantly superior over control (622 kg / ha).

Sharma *et al.* (1997) has tested bio-pesticides for management of *Helicoverpa armigera* in chickpea at Madhya Pradesh, India. Two sprays of insecticides were applied at 20 days interval. Data on mean larval reduction showed superiority of NPV @ 300 LE / ha over other treatments which also produced highest grain yield 1.86 t / ha as against 1.07 t / ha in plots treated with water.

Effect of different insecticides and their combinations on pod borer damage and grain yield of chickpea was studied by Ujagir *et al.* (1997) during 1993-94 and 1994-95. HaNPV @ 500 LE / ha recorded grain yield of 1710 and 1840 kg / ha as against 1120 and 1260 kg / ha in untreated control during 1993-94 and 1994-95, respectively.

Wanjari *et al.* (1998) has evaluated some herbal, chemical and bio-pesticides against *H. armigera* on chickpea. They reported that HaNPV @ 500 LE / ha produced 18.62 q / ha grain yield as against 10.19 q / ha in untreated control and gives incremental cost benefit ration of 1 : 8.41.

Pawar *et al.* (1999) harvested significantly more grain yield (1366 kg / ha) than untreated control when *Helicoverpa armigera* nuclear polyhedrosis virus was applied at 250 LE / ha (1189 kg / ha).

Efficacy of bio-pesticides against *Helicoverpa armigera* on chickpea was tested by Loganathan *et al.* (2000) at Kurumpapalayam and Sarvanampatti in

Coimbatore district during summer 1997. At both the places HaNPV @ 1.5 X 10 ^{12} POB / ha recorded significantly lower larval population of *H. armigera* than untreated check. At Kurumpapalayam larval population in HaNPV treated plots was reduced from initial 2.00 larvae per plant to 0.99 and 1.10; 0.86 and 1.20 ; 0.79 and 0.65 larvae per plant at 3 and 7 days after 1st, 2nd and 3rd spraying, respectively. Whereas at Sarvanampatti larval population was reduced from 1.30 larvae per plant to 0.89 and 1.09; 1.05 and 1.09 ; 0.82 and 0.79 larvae per plant at 2 and 7 days after 1st, 2nd and 3rd spray, respectively. After treatment of chlopyriphos the cost benefit ration was highest in HaNPV treatment i.e. 1:3.32 and 1:4.04 at Kurumpapalayam and Sarvanampatti, respectively.

Bio-efficacy of various insecticides against *Helicoverpa armigera* on chickpea was tested by Bhatt and Patel (2002). Two sprays were given when population of *H. armigera* crossed the economic threshold level. Mean percentage larval mortality at 72 hrs and 1 week after application of HaNPV @ 250 LE / ha were 29.73 and 38.68 per cent after first spray and 31.77 and 38.10 per cent after second spray, respectively. This treatment also recorded yield of 820 kg / ha and cost benefit ratio : of 1 : 2.14 as against 445 kg / ha in plots sprayed with water.

Ramteke *et al.* (2002) has tested the efficacy of neem seed kernel extract in comparison to *Bacillus thuringiensis* L. and HaNPV against *Helicoverpa armigera* (HUB.) on chickpea. The plots treated with HaNPV @ 250 LE / ha with UV protectant recorded significantly lower mean larval population i.e. 12.72, 6.27 and 2.99 per ten plants after 3, 7 and 14 days of spraying as against 18.09, 18.10 and 17.99 per ten plants in plots treated with water.

Musa and Johansen (2003), tested the efficacy HaNPV on pod borer larvae in chickpea at Bangladesh. They reported significantly lower larval population of 15.2 / ten plants in plots treated with HaNPV as against 53.2 / ten plants in untreated plots.

Pharindera Yadav *et al.* (2004) evaluated different microbial bioagents against *H. armigera* during 1998-99 and 1999-2000 at Anand, Gujrat. They reported significantly lower larval population of *H. armigera* in plots treated with HaNPV @ 250 LE / ha i.e. 1.69, 1.65 and 1.56 on five plants at 3, 7 and 14 days after spraying, respectively as against 2.45, 2.06 and 1.95 per five plants in untreated control. It also produced significantly higher yield, (1340.28 kg / ha) than control (937.50 kg / ha).

Efficacy of newer insecticides along with biorationals in chickpea was evaluated by Dhonde *et al.* (2005). Two sprays of HaNPV @ 250 LE / ha caused 62.59 and 68.78 per cent reduction in larval population at 72 hours and 7 days after treatment, respectively. It also gives 17.69 q / ha yield and incremental cost benefit ration of 1 : 6.59 as against 12.20 q / ha yield in untreated control

Nimbalkar *et al.* (2005) compiled the information of bioefficacy of HaNPV against *H. armigera* on various crops during last decade based on research work carried out in Dr. PDKV, Akola. They have recommended the usage of HaNPV @ 250 LE / ha for effective management of *H. armigera* on chickpea, pigeonpea and cotton.

Field efficacy as different microbial agents were tested against gram pod borer by Sidde Gowda and Suhas Yelshetty (2005). Two sprays at seven days interval were applied. They recorded significant reduction of larval population of *H. armigera* from 13.33 to 8.00 and 8.66 larvae per meter row at 3 and 7 days after first spray and from 3.66 to 4.00 and 1.66 larvae per meter row at 3 and 7 days after second spray, respectively.

2.1.3 Efficacy of *Bacillus thuringiensis* against *H. armigera*

Different doses of dipel, HD-1 strain of *Bacillus thuringiensis* Berliner were evaluated against 3rd and 5th instar larvae of *Heliothis armigera* Hubner on gram. An application of 12.00 X 10^9 IU / ha (700 g / ha) against 3rd instar and 16.00 X 10^7 IU / ha (1000 g / ha) against 5th instar was found effective causing 100 % control of test insect within 96 hours after treatment (Dabi *et al.* 1979).

Pathogenicity of various formulations of Bt and cultures of NPV against *Heliothis armigera* (Hb.) was tested by Odak *et al.* (1982) on chickpea. Bactospine (*Bacillus thuringiensis*) and thuricide were highly pathogenic to larvae, causing 70-10 % mortality in the laboratory and 20-65 % mortality in the pot experiment.

A laboratory experiment was conducted by Dabi *et al.* (1988) to determine the potentiality of low rate of *Bacillus thuringiensis* with sublethal dose of insecticides against fifth instar larvae of *H. armigera* on gram. Sublethal dose of insecticides (0.02 %) and Dipel (8000 IU / mg) gave less than 50 per cent kill at 72 hours after treatment.

In field trial Kulkarni and Amonkar (1998) studied relative toxicity of *Bacillus thuringiensis* var Kenyae (ISPC-1), *Bacillus thuringiensis* var Kurstaki (ISPC-4) and *Bacillus thuringiensis* var Kenyae (ISPC-7), each at a dose of 10^9 spores / ml against natural infestation of *H. armigera* in Bengal gram field. First spray of *Bacillus thuringiensis* varieties was given 37 days after sowing. Subsequently, three more sprays were applied at an interval of 15 days. The results indicated definite decrease in the larval counts after every treatment, indicating that isolates were effective in suppressing the larval population in the field.

The efficacy of two bio-insecticides eclar (nuclear polyhedrosis virus of *Helicoverpa* spp and dipel (spores of *Bacillus thuringiensis*) was evaluated by Ali *et al.* (1993) along with the chemical insecticide cypermethrin (1 ml / lit) against *H. armigera* in chickpea. The bio-insecticides were not as effective as chemical insecticide in controlling *H. armigera* infestation. However, they significantly reduced *H. armigera* number as compare to control plot. The yield of chickpea was significanly greater in bio-insecticide treated plot and was statistically similar to that of plot treated with cypermethrin.

Field efficacy of HaNPV alone and in combination with delfin for the control of gram pod borer, on chickpea was tested by Srinivisan *et al.* (1994). Following 6 spray application between 30 to 90 days after sowing they found that from the 3rd spray onwards all the treatment on per with each other. The cost benefit analysis indicated that Bt either alone or in combination with NPV proved uneconomical due to its high cost.

Tustin *et al.* (1994) studied the interaction of nuclear polyhedrosis virus and *Bacillus thuringiensis* as bactospeine against 2nd instar larvae of *Helicoverpa armigera* and revealed that Bt at 300 mg / L produced 32.5 % mortality.

Field efficacy of two commercial mixed formulations, spark and polytrin-C as well as tank mix formulation of cypermethrin and delfin (*B. thuringensis* var karstaki) @ 1 kg / ha were evaluated by Pal *et al.* (1996) for controlling *H. armigera* on chickpea. They reported that Bt applied alone was found to be effective against this pest and caused reduction in larval number to the extent of 3-4 larvae / plant upto 8 days of treatment, compared to the control plots, where larval numbers were very high (8-10 larvae / plants).

Bacillus thuringiensis at different doses in comparison with other chemical insecticides were evaluated by Mathur *et al.* (1997) for the control of *H. armigera* in chickpea. The results indicated that two sprays of Bt krustaki (delfin @ 1000 g / ha) at fortnight interval brought effective reduction in pod damage and enhanced grain yield (9.25 q / ha).

Ujagir *et al.* (1997), studied the effect of different insecticides and insecticide combinations on pod borer damage and grain yield of chickpea during 1993-94 and 1994-95 at Uttar Pradesh, India. They reported that treatment of Bt @ 1 Lit / ha produced significantly higher grain yield 1330 and 1290 kg / ha than untreated control which produced 1120 and 1260 kg / ha, during 1993-94 and 1994-95, respectively.

A field experiment for the evaluation of *Bacillus thuringiensis* (Bt), nuclear polyhedrosis virus (NPV) along with neem seed kernel extract and recommended insecticide, endosulfan was conducted by Sanap and Sarode (1998) for the control of *H. armigera* infesting chickpea. The result indicated that treatment with *Bacillus thuringiensis* @ 1000 g / ha recorded minimum larval population of 1.66 and 2.0 larvae per five plants at 3 and 7 days after applications, respectively. However, highest grain yield (20.65 q / ha) was harvested from the plots treated with endosulfan (0.07 %) followed by Bt.

Effect of various plant protection chemicals was tested by Saxena *et al.* (1998) against *H. armigera* infesting chickpea. They reported that treatment of endosulfan @ 0.07 % produced highest grain yield (1890 kg / ha) and was followed by HaNPV @ 500 LE / ha (1710 kg / ha) and *Bacillus thuringiensis* @

1 lit / ha (1405 kg / ha). Whereas, the lowest grain yield of 1105 kg / ha was harvested from control plot.

Field experiment on management of *H. armigera* (Hub.) on chickpea with some herbal, chemical and bio-pesticides was conducted by Wanjari *et al.* (1998). It was revealed that Bt kurstaki (dipel) @ 0.75 lit / ha) was effective in reducing larval population of *H. armigera* to the extent of 80.84 and 83.29 per cent at 2 and 7 days after spraying, respectively. Similarly this treatment produced higher grain yield (18.95 q / ha), but proved economically less effective than the other treatments.

Pawar *et al.* (1998) evaluated two formulations of Bt along with HaNPV and three recommended chemical insecticides against *H. armigera* in chickpea. They reported that both the Bt formulations viz, Bt halt (750 and 1000 gm / ha) and Bt delfin @ 750 gm / ha produced significantly higher grain yield of chickpea i.e. 1388, 1600 and 1255 kg / ha, respectively than untreated control (1189 kg / ha).

Efficacy of bio-pesticides against *H. armigera* on chickpea was tested by Loganathan *et al.* (2000) at Kurumpapalyam and Saravanampatti in Coimbatore district during summer 1997. The treatments was applied 3 times at 7 days interval. At Kurumpapalayam they reported that, after application of Bt (spicturin @ 1 l / ha) the larval population was reduced from initial 1.50 larvae per plant to 1.10 and 1.26 and 0.96 and 1.26, 0.86 and 0.96 at 3 and 7 days after application of 1st, 2nd and 3rd spray, respectively. Similarly at Saravanampatti the initial larval population of 1.20 per plant was reduced to 0.97 and 1.20; 1.03 and 1.26 and 0.90 and 0.96 per plant at 3 and 7 days after treatment, respectively.

The bio-efficacy of HNPV and *Bacillus thuringiensis* var Kurstaki, individually and in combination with insecticides was evaluated on chickpea against *Helicoverpa armigera* (Hubner) Hardwick during *rabi* season 1998-99 by Bhatt and Patel (2002). They reported that *Bacillus thuringiensis* var kurstaki @ 1 kg / ha causes 28.67 and 38.50 per cent mean larval mortality 72 hrs and 1 week after application of first spray, respectively. Similarly after application of second spray the mean per cent larval mortality was 28.76 and 34.86 per cent, respectively. They also reported yield of 830 kg / ha and CBR of 1 : -0.74 in the plots treatment with Bt.

Pharindera Yadav *et al.* (2004) tested the efficacy of microbial bio-pesticides against *Helicoverpa armigera* on chickpea. They reported that, treatment of Btk (delfin WG @ 1 kg / ha) was effective in reducing the larval population from 2.76 per five plants to 1.52, 1.25 and 1.57 per five plants at 3, 7 and 14 days after application of treatment, respectively. They also recorded significantly higher grain yield of 1513.89 kg / ha as against 937.50 kg / ha in control.

Dhonde *et al.* (2005) tested the efficacy of newer insecticides along with bio-rationals against *Helicoverpa armigera* (Hubner) in chickpea. They reported that treatment of Btk 1000 g / ha was moderately effective against *H. armigera* and causes 74.27 and 71.89 per cent larval reduction at 72 hours and 7 days after treatment, respectively. It also produced significantly higher grain yield (17.98 q / ha) than untreated control (12.20 q / ha) with ICBR of 1 : 3.07.

Effect of microbial insecticides on the larval population of *H. armigera* during 1998-99 was studied by Sidde Gowda and Suhas Yelshetty (2005). They reported that different sources of *Bacillus thuringiensis* (delfin, biolep, halt and

Bt var kenyae) significantly reduced the larval population at 3 and 7 days after application of first spray than untreated check. But the larval population in all the treatments were at par with untreated check at 3 and 7 days after application of second spray. Amongst the various Bt formulations Bt. Var kenyae recorded highest grain yield (9.40 q / ha) followed by halt (8.70 q / ha).

2.1.4 Efficacy of biopesticides in combination with other biopesticides

A field trial to investigate the efficacy of HaNPV alone and in combination with delfin for the control of gram pod boer, *Heliothis armigera* (Hubner) on chickpea was conducted by Srinivisan *et al.* (1994). They found that, combined treatment of HaNPV @ 125 LE / ha + *Bacillus thuringiensis* @ 1 kg / ha was as effective as individual application of HaNPV @ 250 LE / ha, but statistically superior to endosulfan in the first two sprays.

Tustin *et al.* (1994) studied the interaction of nuclear polyhedrosis virus (NPV) (0.3 X 10^5 POB / ml) and *Bacillus thuringiensis* as bactospeine (300, 600 mg / l) against 2nd instar larvae of *H. armigera*. They revealed that *Bacillus thuringiensis* at 300 mg / l produced 32.5 % mortality and in combination with NPV produced 25 % mortality.

Loganathan *et al.* (2000) evaluated various doses of spicturin either alone or in combination with HaNPV against *H. armigera* on chickpea at Kurumpapalayam and Saravanampatti in Coimbatore district. At Kurumpapalayam combined application of spicturin @ 1.00 lit / ha + HaNPV @ 1.5 X 10^{12} POB / ha recorded less larval count i.e. 0.96 and 1.07 and 0.60 and 0.90 per plant at 3 and 7 days after first and second spray, respectively than their individual applications. But cost benefit ratio of this treatment was less (1 : 2.07) than the treatments with their individual applications. Similar type of results were also recorded at

Saravanampatti where 0.86 and 1.03 and 0.86 and 1.00 larvae per plant were recorded at 3 and 7 days after first and second spray, respectively.

Bhatt and Patel (2002) revealed that, the combine application of HaNPV @ 125 LE / ha + *Bacillus thuringiensis* var krustaki @ 0.5 kg / ha was more effective than individual application of HaNPV @ 250 LE / ha and *Bacillus thuringiensis* var krustaki @ 1 kg / ha. Combine application of HaNPV + Btk produced 42.71 and 50.02 per cent mean larval mortality at 72 hr and 1 week after first spray. The corresponding mean percentage larval mortality after 72 hr and 1 week after second spray was 43.16 and 51.12 per cent, respectively. The combine application of treatment, also produced higher grain yield of 980 kg / ha and cost benefit ration of 1 : 0.69.

Phadtare *et al.* (2004) tested the compatibility of entomogenous fungus, *Beauveria bassiana* with microbial pesticides against *Helicoverpa armigera* under laboratory condition. They found that application of HaNPV @ 2 X 10^{9} spores / ml and *Bacillus thuringiensis* @ 2 g / l either alone or in combination with *Beauveria bassiana* @ 1.2 X 10^{5} spores / ml produced significantly higher mean per cent larval mortality than *Beauveria bassiana* alone (1.2 X 10^{5} spores / ml). Application of *Bacillus thuringiensis* either alone or in combination with *Beauveria bassiana* and produced cent per cent mortality at 10 days after treatment. Whereas individual application of HaNPV was more effective than its combination with *Beauveria bassiana*.

2.1.5 Efficacy of spinosad against *H. armigera*

Dandale *et al.* (2000) tested the efficacy of spinosad against the cotton bollworms in comparision with some synthetic pyrethroids during 1998-99 and 1999-2000. Efficacy of spinosad 48 SC @ 50 and 75 g a.i. / ha in comparison with two newer synthetic pyrethroids, i.e decis (decamethrin) tablets, 10 and 12.5 g a.i. / ha and bulldock (betacyfluthrin) 2.5 EC 12.5 and 18 g a.i. / ha against cotton bollworms. Spinosad 48 SC, 75 and 50 g a.i. / ha was found most effective in controlling the infestation of *H. armigera* in green fruiting bodies on plant 14 days after treatment.

Vadodaria *et al.* (2001) studied bio-efficacy of newer insecticides against bollworms of cotton. Three years pooled results indicated that the spinosad 48 SC at 75 g a.i. / ha and bulldock 2.5 SC at 18 g a.i. / ha recorded lower larval population, minimum damage to squares, bolls and locules with higher seed cotton yield.

Insect growth regulators and microbial insecticides was evaluated by Saindane (2002) against cotton bollworms. Amongst the different insect growth regulators and microbial insecticides spinosad 50 g a.i. / ha recorded minimum infestation in green fruiting bodies due to bollworm complex at 7 and 14 days after sprayings. This treatment also recorded highest yield of seed cotton.

Similarly, Dhonde *et al.* (2005) tested newer insecticides along with biorationals against *H. armigera* in chickpea. They reported that spinosad @ 75 g a.i. / ha causes 83.14 and 81.18 per cent reduction in larval population at 72 hours and 7 days after application of treatment. This treatment also recorded more grain yield (19.00 q / ha) as against 18.27 q / ha in endosulfan @ 350 g a.i. / ha and 12.20 q / ha in untreated control and gave ICBR of 1 : 3.66.

Similarly, Jesmi Vijayan (2005) evaluated some newer insecticides and bio-agents for the management of major pests of tomato. Some newer insecticides such as imidacloprid 17.8 EC @ 0.004 %, thiamethoxam 25 WG @ 0.003 %, quinalphos 25 EC @ 0.05 %, spinosad 45 SC @ 0.01 %, Bt (delfin) @ 1000 g / ha, neem oil 1 %, NSKE 5 %, HaNPV @ 250 LE / ha, endosulfan 35 EC @ 0.05 % and bioagents viz., *Trichogramma chilonis* @ 1.5 lakh parasitized eggs / ha and *Chrysoperla carnea* @ 10000 eggs / ha. She reported lowest fruit borer infestation on number and weight basis and highest tomato fruits with 1 : 4.88 ICBR in treatment with spinosad.

Gaikwad and Bhamare (2006) tested efficacy of newer insect growth regulator and insecticides against cotton bollworms during 2002-03. The results revealed that spinosad 45 SC @ 50 g a.i. / ha, betacyfluthrin 2.5 EC @ 12.5 g a.i. / ha and indoxacarb 14.5 SC at 50 g a.i. / ha were found most effective in reducing bollworm damage and producing highest yield.

2.1.6 Efficacy of endosulfan against *H. armigera*

Field trials was conducted by Singh *et al.* (1973) for the chemical control of gram pod borer, *Helicoverpa armigera* (Hubner) on gram during 1970-71 in Punjab. They found that all the insecticides treatments viz., carbaryl (1.75 kg a.i. / ha), DDT (1.75 kg a.i / ha), endosulfan 0.49 kg a.i. / ha and DDT + endosulfan (1.75 + 0.49 kg a.i. / ha) were equally effective in reducing pod borer infestation as well as in producing higher grain yield. However, cost benefit analysis of these treatments showed that endosulfan and DDT were most economical over other chemical insecticides.

The comparative efficacy of different pesticides was evaluated by Agrawal *et al.* (1977) against gram pod borer, *H. armigera* on gram. Their results indicated that the sprays of monocrotophos @ 875 ml / ha, chlorpyriphos @ 1 litre / ha and endosulfan @ 1.4 litre / ha were most effective in reducing the damage due to *H. armigera* and increasing the yield.

Mishra and Saxena (1981), studied the efficacy of some promising insecticides viz, monocrotophos (0.04 %), endosulfan (0.07%) and quinalphos (0.05%) against *H. armigera* on gram. They reported that treatment of endosulfan produced significantly higher grain yield (1964 kg / ha) than untreated control (982 kg / ha).

While evaluating comparative efficacy of various insecticide formulations against *H. armigera* on chickpea in Harayana, Dahiya *et al.* (1983) found that the plots treated with endosulfan (0.07 %) recorded significantly lower pod damage and maximum grain yield (24.99 q / ha) than untreated control.

The effectiveness of six insecticides was evaluated by Yadav and Yadav (1983) against *H. armigera* on kabuli gram in Haryana. Application of endosulfan (0.07 %); phosalone (0.07 %) quinalphos (0.05%), chlorpyriphos (0.04%), fenitrothion (0.05%) and fenvalerate (0.04 %) were made at 50 per cent pod formation stage. The result showed that endosulfan (0.07 %) was proved to be most effective in reducing pod damage and increasing grain yield (11.80 q / ha) as compared to other treatments.

Bio-efficacy of various chemical insecticides was tested by Chari *et al.* (1985) against *H. armigera* on chickpea. The results indicated that all the insecticides were effective in reducing larval population of the pest. However, endosulfan @ 2000 ml / ha effectively lowered down the larval population from initial 2.53 per plant to 1.27, 1.25 and 1.11 per plant after 3, 7 and 14 days of spraying, respectively.

Chhabra and Kooner (1985) tested two different doses of pyrethroids viz., cypermenthrin, deltamethrin, fenvalerate and permethrin in comparison with endosulfan against *H. armigera* on gram. They found that supremacy of the test chemicals was consistently better than control throughout the three cropping seasons of 1980-83. However, they concluded that on the basis of efficacy and grain yield levels, performance of fenvalerate, cypermethrin (both @ 60 g a.i. / ha) deltamethrin (@ 15.9 a.i. / ha) and endosulfan (@ 262.5 g a.i. / ha) was the best.

The field trials were conducted during 1978-79 and 1980-81 by Rizvi *et al.* (1986) to evaluate the efficacy and economic of six insecticides viz., chlorpyriphos, phosalone, fenitrothion, quinalphos, diazinon and endosulfan at a concentration of 0.05 per cent for the management of *H. armigera* on gram. The results showed that all the insecticides were found effective. However, three sprays of endosulfan and quinalphos at 15 days interval commencing at 50 per cent flowering of gram gave the most effective control of gram pod borer and proved to be more economical treatment than other.

Gunasekaran and Balasubramanian (1987) evaluated diflubenzuron (@200 to 600 g a.i. / ha) and endosulfan (@525 a a.i. / ha) for the control of *H. armigera* on chickpea. They reported that endosulfan causes 75.26, 87.60 and 98.15 percent reduction in population of larvae after 1, 3 and 7 days of spraying, respectively.

Different doses of nuclear polyhedrosis virus (HNPV) in comparison with endosulfan (@ 0.05 %) were evaluated by Pawar *et al.* (1987) against *H. armigera* on chickpea. They reported that application of endosulfan reduced larval population of *H. armigera* from initial 2.25 to 0.95 and 0.65 at 7 and 14 days after first spraying, and further to 0.25 and 0.00 at 7 and 14 days after second spraying, respectively. They also reported significantly higher grain yield in plots treated with endosulfan (1605 kg / ha) than plots treated with water (1146 kg / ha)

Sanap and Deshmukh (1987) tested various insecticides against *H. armigera* on chickpea and observed that two applications of endosulfan (0.07%) at 50 per cent flowering and 15 days thereafter proved to be most effective in reducing pod damage and producing highest grain yield (1209 kg / ha).

A field trial was conducted by Thakur *et al.* (1988) in Madhya Pradesh, India to determine the comparative efficacy of neem seed kernel extract, neem leaf extract both at 5 per cent concentration and some commonly used insecticides viz., endosulfan (0.07 %), monocrotophos (0.04 %) carbaryl (10 % dust). BHC (10 % dust), quinalphos (1.5 % dust) and methyl parathion (2 % dust) against *H. armigera* on gram. The results indicated that all the chemical insecticides were more effective than neem formulations in reducing larval population. However, among all the treatments endosulfan recorded maximum increase in grain yield (45.5 %) over control.

The efficacy of six insecticides was evaluated by Deka *et al.* (1989) against *H. armigera* in chickpea. They reported that endosulfan (@ 500 g a.i. / ha) was most effective in reducing the larval population and producing higher grain yield than untreated control.

Kaul *et al.* (1989) carried out investigations on the chemical control of gram pod borer *H. armigera* on gram with some synthetic pyrethroids (fenvelerate 0.01 and 0.02 %, cypermethrin 0.006 and 0.009 %, decamethrin 0.002 and 0.004) in comparision with endosulfan (0.07 %). They observed that treatment of endosulfan was more effective in minimising pod damage and also recorded highest yield of 1100 kg / ha.

The comparative efficacy and economics of eleven pyrethroids and non-pyrethroid insecticides were studied by Parsai *et al.* (1989) against *H. armigera* on chickpea. The results showed that among the various treatments endosulfan (0.07 %) and monocrotophos (0.05 %) were found to be effective. However, highest economic returns were obtained from endosulfan with cost benefit ratio of 1 : 5.15.

Gupta and Thakur (1990) studied the bio-efficacy and economics of five insecticides viz., monocrotophos, endosulfan, fenvalerate, decamethrin and cypermethrin along with two non-edible vegetable oils, viz., neem and karanj oil against *H. armigera* on chickpea. They observed that plots treated with endosulfan (0.08 %) reduced larval population at 2 and 5 days after spraying with a mean of 0.9 larvae per meter row length and recorded highest grain yield (2220 kg / ha). However endosulfan (0.06 %) proved to be the most economical treatment followed by endosulfan (0.08 %) with a cost benefit ratio of 1 : 14.4 and 1 : 12.1, respectively.

Efficacy of nuclear polyhedrosis virus and endosulfan 0.05 % were compared for the control of *H. armigera* on chickpea by Pawar *et al.* (1990) for three years (1984-1988) in Maharashtra, India. Virus was applied at 100, 250 and 500 LE / ha alone or with endosulfan. All the treatments, except the lowest concentration of virus alone and with endosulfan, significantly increased grain yield. The lowest pod damage (3.84 %) and highest yield (1379 kg / ha) were observed in plots treated with two sprays of endosulfan alone.

Rabindra *et al.* (1991) reported that endosulfan @ 350 g a.i. / ha was significantly effective over individual application of NPV @ 250 LE / ha. They reported significantly less larval population 4.7 and 4.7 ; 3.3 and 3.0 at 3 and 7 days after 1st and 2nd spray, respectively.

The efficacy of eight different insecticides viz., endosulfan (0.07 %), monocrotophos (0.05 %), quinalphos (0.07 %), decamethrin (0.003 %), fenvalerate (0.005 %) cypermethrin (0.004 %), carbaryl (0.10 %) and methyl parathion (0.05 %) was determined by Mehta *et al.* (1991) against *H. armigera* on gram. The results indicated that all the chemicals were effective in reducing the pod borer damage as comapre to untreated control. Whereas, endosulfan recorded 13.93 per cent pod damage as well as produced yield of 853 kg / ha, while the control plot recorded 32.06 per cent pod damage and lowest yield of 597 kg / ha.

Field trial was conducted to test the efficacy of endosulfan and herbal products alone and in combination with nuclear polyhedrosis virus against gram pod borer, *H. armigera* (Hb) by Supare *et al.* (1991). They observed that endosulfan alone (0.07 %) and its combination with HNPV (@ 250 LE / ha) were equally effective in reducing the larval population and produced higher yield of grains (18.97 q / ha) as comapre to untreated control (6.87 q / ha)

A field experiment was carried out by Verma *et al.* (1992) to know the optimum time and number of sprays of endosulfan for the control of *H. armigera* infesting chickpea. Two sprays of endosulfan (35 EC @ 1200 ml / ha) at flowering and podding stage of crop exhibited better results with minimum pod damage (2.62 %) and higher grain yield (798.39 kg / ha). This spray schedule also proved economically effective against pod borer with a cost benefit ratio of 1 : 3.7.

Sinha (1993) tested the field efficacy of diflubenzuron, neem oil and neem seed kernel extract in comparison with endosulfan (0.07 %) against *H. armigera* infesting chickpea during two years. He observed that treatments with endosulfan causes highest reduction in pod borer infestation i.e. 57.6 and 52.8 per cent and also recorded highest seed yield 18.5 and 27.7 q / ha during 1986-87 and 1988-89, respectively. However, during 1989-90 he evaluated some new products and chitin biosynthesis inhibitors along with endosulfan, and reported significantly higher seed yield in endosulfan 0.07 % (19.2 q / ha) than untreated control (9.7 q / ha).

The work carried out at National Agricultural Research Project in Karnataka by Girraddi *et al.* (1994) revealed that the plot which received two sprays of endosulfan (0.07 %) at 50 per cent flowering and green pod stage recorded lower pod damage (2.9 and 4.7 %) as well as higher seed yield (9.8 and 10.7 q / ha) during the year 1988 and 1989, respectively and also gave highest cost benefit ratio as compared to other treatments which received two or more number of sprays.

Shukla *et al.* (1996) studied the efficacy of three concentrations (250, 300 and 350 larval equivalents per ha.) of nuclear polyhedrosis virus in comparison with endosulfan. They reported significantly highest seed yield 1.60 t / ha in plots treated with endosulfan as against 1.17 t / ha in untreated control.

Datkhile *et al.* (1996) conducted field experiments for the control of gram pod borer on chickpea during *rabi* seasons of 1989-90, 1990-91 and 1991-92. Three applications of different insecticides were given at an interval of 15 days. Pooled analysis revealed that, endosulfan @ 0.07 % causes 69.9, 24.6 and

61.6 per cent reduction of *H. armigera* larvae at 2,7 and 15 days after spraying, respectively. It also produced significantly higher grain yield (15.4 q / ha) than untreated control (10.7 q / ha).

Vyas and Lakhchaura (1996), tested efficacy of nuclear polyhedrosis virus alone or in combination with chemical insecticides. They reported that chemical insecticides were superior over NPV and gave low pod damage. They recorded significantly highest grain yield (1077 kg / ha) when two sprays of endosulfan were given at 50 % flowering with an interval of 15 days.

The field experiment was conducted by Ravi and Verma (1997 a) to test the efficacy of varous insecticides against *H. armigera* on chickpea. The results showed that endosulfan (0.07 %) effectively reduced larval population from 7.33 larvae per ten plants to 1.00 and 0.67 larvae per ten plants at 5 and 10 days after second spraying, respectively. Similarly, this treatment recorded 2124 kg / ha grain yield with maximum cost benefit ration (1 : 7.38).

Sharma *et al.* (1997) evaluated nuclear polyhedrosis virus (@ 300 LE / ha), *Trichgramma chilonis* @ 250000 / ha) monocrotophos @ 600 ml / ha and endosulfan @ 1200 ml / ha against *H. armigera* on chickpea. They reported that NPV was effective over endosulfan in reducing larval population but produced equal grain yield (1.86 t / ha) as that of endosulfan.

Ujagir *et al.* (1997) evaluated some bio-pesticides, chemical insecticides and their combinations against *H. armigera* on chickpea The pooled data of two years showed that endosulfan was effective in reducing pod borer damage and also produced highest grain yield (1860 kg / ha), than untreated control (1190 kg / ha)

Wanjari *et al.* (1998) made efforts to manage *Helicoverpa armigera* on chickpea with some herbal, chemical and bio-pesticides. They recorded significantly higher grain yield of chickpea (19.27 q / ha) in endosulfan treated plot as against 10.19 q / ha in untrated control.

Different concentration of *Bacillus thuringiensis*, *Helicoverpa armigera* nuclear polyhedrosis virus were evaluated in comparison with chemical insecticides (fenvalerate, chlorpyriphos and endosulfan) against *H. armigera* on chickpea by Pawar *et al.* (1999). They reported significantly lower pod damage (9.59 %) and higher grain yield (1522 kg / ha) than untreated control which recorded highest pod damage (22.90 %) and lowest grain yield (1189 kg / ha)

The bio-efficacy of HNPV and *Bacillus thuringiensis* var kurstaki, individually and in combination with insecticides (endosulfan, fenvalerate, monocrotophos, nimecidine and tobacco snuff decoction) were evaluated by Bhatt and Patel (2002). They reported that endosulfan @ 0.07 % causes 51.92 and 62.83 per cent mean larval mortality at 72 hrs and 1 week after first spraying and 54.28 and 63.27 per cent mean larval mortality at 72 hrs and 1 week after second spraying, respectively. This treatment also produced significantly highest grain yield (1130 kg / ha) with net cost benefit ratio of 1 : 10.09.

Ramteke *et al.* (2002) tested the efficacy of some botanicals, and microbial pesticides in comparison with endosulfan against *H. armigera* on chickpea. They reported significantly lower larval population in treatment of endosulfan (0.07 %) i.e. 8.05, 7.38 and 6.33 larvae per ten plants at 3, 7 and 14 days after spraying than untreated control, where corresponding larval population per ten plants was 18.09, 18.1 and 17.99 after 3, 7 and 14 days of spraying, respectively.

Pharindera Yadav *et al.* (2004) tested the efficacy of microbial bio-pesticides in comparison with endosulfan against *Helicoverpa armigera* on chickpea. The results revealed that endosulfan @ 0.07 % reduced the larval population from initial 2.57 to 1.67, 1.03 and 1.63 larvae per five plants at 3, 7 and 14 days after spraying, respectively.

Dhonde *et al.* (2005) tested the efficacy of newer insecticides along with biorationals against *Helicoverpa armigera* on chickpea. The results revealed that endosulfan @ 350 g a.i. / ha was effective in reducing the larval population and pod damage. It also yielded 18.27 q / ha chickpea grains as against 12.20 q / ha in untreated control and gave incremental cost benefit ration of 1 : 13.69.

2.2 Efficacy of modules against *H. armigera*

Integrated management of *Helicoverpa armigera* on gram was studied by Sanap and Pawar (1998) during 1993-96 at Rahuri (M.S.). The results of trial revealed that 3 spray applications starting from initiation of flowering and subsequent 2 sprays at fortnightly intervals with first two sprays either with nuclear polyhedrosis virus @ 250 LE / ha or neem seed kernal extract 5 % followed by third spray with endosulfan 0.07 % were most effective in controlling the gram pod borer and gave highest grain yield of 2200 and 2206 kg / ha, respectively. These two treatments were followed by treatment with first spray of NSKE @ 5 % followed by NPV @ 250 LE / ha and endosulfan @ 0.07 %. The treatment with three spray of endosulfan gave 2049 kg / ha grain yield. The highest returns per rupee investment was obtained from treatment with first two sprays of

NSKE and third spray of endosulfan (4.28) and was followed by treatment with three spray of endosulfan (2.57).

Kumawat and Jheeba (1999) carried out field trials for ecofriendly management of *H. armigera* on chickpea from 1993 to 1996. The result of trial revealed that the treatments with alternate spray of monocrotophos and endosulfan resulted in lowest pod infestation and highest seed yield but this treatment was not significantly different from alternate spray of NPV and endosulfan. The chemical treatment also give maximum net return followed by the NPV alternated with endosulfan treatment.

Singh *et al.* (2000) evaluated some IPM module against *Helicoverpa armigera* in chickpea during 1995-96, 1996-97 and 1997-98 under irrigated as well as rainfed conditions. All the IPM modules tested were found significantly superior over the untreated control. Minimum pod damage and maximum grain yield was observed in module 1 consisted of HaNPV @ 250 LE / ha -- Btk @ 1500 ml /ha – endosulfan @ 1250 ml / ha in both irrigated and unirrigated conditions. Module 2 in which second spray of Btk of module 1 was replaced with nimbicidine, was second best in controlling *H. armigera* and gave maximum benefit cost ratio due to low cost of nimbicidine.

Sarode and Sonalkar (2000) conducated field experiments at four blocks of the university to compare the biocontrol and convectional methods of pest management in chickpea. Although both the methods were effective in managing the pest problem, the bio-control method performed comparatively better in respect of larval population of *H. armigera* have less pod damage and higher yield.

Patel *et al.* (2002) evaluated various modules for IPM in Pigeonpea at Anand during 1996-1999. Amongst various modules studied, they found that GAU

IPM model consist of installation of pheromone trap for *H. armigera* @ 10 trap / ha during third week of November to third week of January, spray of HaNPV @ 250 LE / ha during third week of November, spray of NSKE 5 % at flowering at fourth week of November and spray of monocrotophos 0.04 % on pod setting during 2^{nd} week of December followed by endosulfan 0.07 % during 4^{th} week of December could effectively manage the population of *Helicoverpa armigera* and gave highest grain yield than other modules.

The field trial conducted at ANGRAU, Hyderabad for bio-intensive pest management in pigeon pea revealed that alternate spray of HaNPV and NSKE (HaNPV – NSKE - HaNPV - NSKE) fared better in supresssion of *H. armigera* larval population (2.00) followed by three spray of endosulfan followed by HaNPV - NSKE – HaNPV – NSKE and Bt – NSKE – Bt – NSKE alternations (Anonymous 2003 b).

Demonstration of Bt – HaNPV – Bt – HaNPV alternations in pigeon pea for management of pod borer complex at TNAU, Coimbatore showed that Bt, HaNPV alternations (Bt @ 1.0 kg / ha – HaNPV @ 1.5 X 10^{12} POB / ha - Bt @ 1.0 kg / ha – HaNPV @ 1.5 X 10^{12} POB / ha) was effective in reducing *H. armigera* population and produced 1828 kg / ha grain yield as against 886 kg / ha in untreated control (Anonymous, 2003 c).

Khajuria *et al.* (2006) taken preliminary observations on field evaluation of some ecofriendly modules in the management of *H. armigera* on tomato. Three eco-friendly modules viz., module 1 (M_1) comprising of *Bacillus thuringiensis* var kurstaki (Btk) @ 1 kg / ha, Btk @ 0.5 kg / ha + fenvalerate @ 0.5 lit. / ha, sex pheromone @ 3 *Helicoverpa* lure (HL) / ha, HaNPV @ 250 LE / ha, HaNPV 125 LE / ha + Fenvalerate @ 0.5 lit. / ha and endosulfan 35 EC @ 1 lit / ha, module 2

(M_2) comprising of NSKE 5 %, HaNPV @ 250 LE / ha, sex pheromone trap @ 3 HL / ha, Btk @ 1 kg / ha and decamethrin 25 EC @ 1 lit / ha and moduel 3 (M_3) consisting of Btk @ 1 kg / ha (twice), sex pheromone trap @ 3 HL / ha, HaNPV @ 250 LE / ha (twice) and malathion 50 EC @ 1 lit / ha were evaluated for the management of tomato fruit borer. The observations revealed that all the three modules were significantly better over the untreated control (M_0) in terms of pest population, yield and per cent infestation. The mean number of larvae per plant recorded two days after application of each treatment under each module were significantly less (5.58 / plant) in M_1 as compared to M_2 (7.16 / plant) and M_3 (6.16 / plant). The module M_1 also produced highest fruit yield than M_2 and M_3.

2.3 Seasonal incidence of *H. armigera* on chickpea

Vaishampayan and Veda (1980) studied tha population dynamics of gram pod borer, *Helicoverpa armigera* (Hubner) and its outbreak situation on gram, *Cicer arietinum* L. at Jabalpur. Five years data on seasonal changes in the larval population of gram pod borer revealed that rainfall is one of the important key factors that influenced the build-up of larval population on gram crop. It showed highly significant and positive correlation with larval population. Whereas, relative humidity had shown significantly negative correlation with larval population. Relative humidity below 75 % was considered an alarming level and sure indicator of high population build-up of pest on gram during the major active period from December to February. No direct and general relationship could be established between temperature and pest population level. However positive correlation was observed between mean minimum daily temperature and build-up of pest population. The temperature ranged between 10 to 14 ^{o}C proved to be most favorable and optimum for pest development. However, the activity of pest was found to be retarded sharply at temperature below 8 °C. They also found positive correlation between the activity of parasite and density of its host.

Yadava *et al.* (1985) studied the relationship between certain biotic and abiotic factors and the occurrence of gram pod borer on chickpea in Uttar Pradesh, India. They observed two peaks during the 47th to 50th and 11th to 15th weeks. Population was positively correlated with maximum and minimum temperature and negatively correlated with relative humidity and per cent parasitism by ichneumonid *Compoletis chlorideae*.

Garg (1987) studied seasonal abundance and host ranges of *Heliothis armigera* (Hub.) in the Kumaon hills, India during 1983 and 1984. He observed peak damage to the pods in the first week of May in both the years when the mean temperature range was 10.6 °C to 26.4 °C in 1983 and 7.7 °C to 26.6 °C in 1984. The mean relative humidity was 64.0 % in 1983 and 52.9 % in 1984 during that period.

Influence of abiotic factors on relative abundance of pod borer of chickpea was studied by Yadava *et al.* (1988) in Uttar Pradesh, India during 1981 to 1988. They reported that *H. armigera* was abundant during 47th – 51st and 10th – 17th standard weeks and its abundance was significantly positively correlated with maximum and minimum temperature and significantly negatively correlated with relative humidity.

Anwar and Shafique (1992) studied the incidence of attack and population fluctuations of *Heliothis armigera* in relation to chickpea phenology and environmental factors in the field. The results over three years revealed that the larval population of *H. armigera* remained low in chickpea crop during cool months (December to January). It increases rapidly from February to March with rise-in temperature. The maximum flowering and pod formation stage of crop and relative high temperature (Min. 17 and Max. 27 °C) were optimum for rapid larval population build-up.

Spatial distribution of *Helicoverpa armigera* (Hubner) larvae in chickpea crop was studied by Tomar and Sehgal (1993) at Pantnagar, India. Its incidence initiated during flowering initiation stage i.e. 0.04 and 1.90 larvae per ten plants at 3rd March 1992 and 16th March, 1993, respectively. It then gradually increase and reached its peak at podding stage of crop i.e. 38.9 and 91.80 larvae per ten plants during 7th April 1992 and 20th April 1993, respectively. Afterwards it decrease gradually and was minimum 1.76 and 3.54 larvae per ten plants during 20th April 1992 and 11th May 1993, respectively at corp maturity stage.

Likewise, Patel and Koshiya (1999) studied the population dynamics of gram pod borer (*Helicoverpa armigera* (Hubner) Hardwick on cotton, pigeon pea and chickpea. Their studies revealed that, the pest incidence in chickpea crop commenced during 3rd week of November and reached its peak (6.3 larvae / 10 plants) in 3rd week of December and then gradually decreased. The lowest population (9.3 larvae / 10 plants) was recorded in last week of February when the crop was at maturity stage. The correlation study in chickpea showed that among the various physical factors of environment, minimum and maximum temperature as well as vapour pressure in the morning and evening were negatively correlated with population build-up of this pest.

Metange *et al.* (2002) studied the influence of temperature on incidence of gram pod borer *Helicoverpa armigera* Hubner on chickpea. They found that larval population was positively and significantly correlated with maximum and minimum temperature. Critical maximum and minimum temperature for larval population were found to be 29.5 and 13.3 °C, respectively.

2.4 Biotic complex of *H. armigera*

Population dynamics of *Heliothis armigera* Hubner on sorghum, pigeonpea and chickpea was studied by Bilapate *et al.* 1979 in Marathwada. They found that, causes of mortality of various stages of *H. armigera* were different in different crops. However, in chickpea a larval parasite *Campoletis chlorideae* Uchida was alone responsible for reducing the population of chickpea during November-December.

A field study on larval and pupal parasites was made by Bilapate (1981) on cotton, safflower, sunflower, pigeonpea and chickpea. The per cent parasitization by *C. chlorideae* was minimum (8.70 %) in 18-25 December, 1978. The parasitization due to pupal parasite *Goniophthalmus halli* was minimum (2.96 %) during 5-19 February 1979 and maximum (16.18 %) during 18-25 December, 1978.

The egg parasitism of *H. armigera* was studied by Yadav and Patel (1981) in Gujrat during 1973-74 and 1974-75, by collecting eggs of the pest from tomato, potato, gram and lucern fields. The parasites recorded from the eggs were *T. chilonis* and was a new record from *H. armigera* eggs in Gujrat. The parasite was common in eggs collected from all the plants except gram, this was thought to be due to acidic secretion produced by leaves.

Yadav *et al.* 1982 studied the seasonal activity of *C. chlorideae* Uchida, a larval parasite of *Heliothis armigera* at Anand (Gujrat). They observed that, on gram the parasite was active from second fortnight of December to first forthnight of March and per cent parasitization ranged between 17.3 to 22.5, 14.5 to 37.1 and

1.4 to 35.0 during 1972-73, 1973-74 and 1974-75, respectively. Further, they also observed that, an egg parasite, *Trichograma chilonis* was ineffective in gram but exerted significant pressure against *H. armigera* in potatoes.

The influence of Host-plant resistance on the parasitism of pest larvae was examined in field trial on resistance (ICC-506) and susceptible (Annigeri) cultivars, at three plant densities (8.3, 16.7 and 33.3 plants / m^2) by Sithanantham *et al.* (1982) the lower incidence of parasitism in larvae was noticed from the "resistant" cultivar than in those from the "susceptible" type. The dominant parasitoids recorded were the Hymenopteran *Campoletis chlorideae* and the Dipteran *Carcelia illota*.

Sing *et al.* (1983) recorded the larval parasitoids of *H. armigera* from fruiting bodies of gram and tomato in lab in Haryana from February to April 1981 and observed four parasites. *Apanteles sp.* was the perominant endoparasite parasitizing upto 85 % of larvae while *Bracon hebetor* attacked 11 % of larvae and *C. chlorideae* 4 %.

Yadav *et al.* (1985) studied *Compoletis chlorideae* Uchida, a larval parasitoids of *H. armigera* (Hubner) infesting chickpea for three years from 1979 to 1982. Three years data indicated that the percent parasitization was highest during the month of December and lowest during February and almost nil during March in all the years.

Bilapate *et al.* (1988) studied the mortality factors affecting the noctuid *H. armigera* in the absence of pesticides on arhar, gram and safflower fields in Maharashtra, India. On *Cicer arietinum* L., *C. chlorideae* caused 14.73 % parasitism during the first generation while *Eriborus argenteopilosus* caused 1.53, 16.41 and

10.44 % parasitism during the 1st, 2nd and 3rd generations, the mortality of larvae due to nuclear polyhedrosis virus was 6.88, 1.98 and 24.52 %.

Srinivas (1989) studied the extent of parasitism of gram pod borer *H. armigera* by ichneumonid larval parasites at Coimbatore, India. The parasites were found active from October onward. The maximum parasitization of 43.9 % was recorded by *C. chlorideae* during the first forthnight of December 1984 compared with 18 % with *Eriborus* sp The initial parasitization by *Eriborus* sp started with 6 % during October and reached a maximum of 43.79 % by the last week of January 1985.

Patnaik *et al.* (1991) observed the incidence of *H. armigera* (Hb.) on chickpea and its population phenology in north central pleatu zone in Orissa between 1982 to 1988. They found that the ichneumonid *C. chlorideae* and the tachnid *C. illota* played a key role in suppressing the larval population during poding stage.

Ravi and Verma (1997 b) observed that irrespective of sowing date, the occurrence of parasitization by *C. chlorideae* was paralled to the build up of pest population. The extent of parasitization increased up to 33.3 and 25 % during standard week in normal and late sown crops, respectively and then declined in March because of high temperature.

Sachan and Bhumik (1998) stated that, the extent of natural parasitization by *Campoletis chlorideae* varied between 12.69 and 56.28 % during 1995-96 and 3.57 and 80.64% during 1996-97 on standard weekly basis. Parasitization recorded during 1995-96 was 37.51, 46.10, 42.67, 16.16 and 26.19 % during November, December, January, March and April, respectively.

Feasibility of using mass releases of *Trichogramma chilonis* for the control of *Helicoverpa armigera* on chickpea was studied at Nagpur, Maharashtra, India, during 1994-96 by Kulat *et al.* (1999). Four releases of 1.0 lakh / ha at weekly intervals were carried out. None of the 1763 *H. armigera* eggs collected were parasitized.

Devi *et al.* (2002) studied the natural enemies of *Helicoverpa armigera* Hubner on chickpea from November to May of 1998-2000 in Manipur, India. Five Parasitoids were found associated with *H. armigera* and amongst them *Campoletis chlorideae* was most important natural enemy of this pest. The per cent parasitism ranged from 0.18 to 23.81 % from March to May. The maximum incidence of parasitoids was recorded during the first and second week of April 1998-2000. The data revealed a high positive co-relation between the pest and parasitoids.

2.5 Effect of malic acid larval and pupal development of *H. armigera*

Reed *et al.* (1979) reported that, acidic fraction of chickpea consists of 94.2 % malic acid, 5.6 % oxalic acid and 0.2 % acetic acids.

The chickpea plant secretes an exudate that is visible as droplets on the velvet like cover of hairs on all its green parts. This very acidic material may be responsible for the relatively small range of insect pest found on chickpea (Rambold, 1981).

Chaudhary and Sharma (1981) studied the biology of gram pod borer, *H. armigera* on chickpea in Haryana. They recorded five larval instars and the duration of larval stage averaged 15.5-29.9 days during different months from November to April. Pupation took place in earthen cocoon and the pupal period averaged 2.4 to 6.7 days.

Ghosh *et al.* (1986), studied the biology of gram pod borer *H. armigera* during February-April 1981. They found that larvae took on an average 26.6, 4.8 and 20.6 days for completion of larval, pre-pupal and pupal period during February with average temperature 18.5 ± 7.3 °C and relative humidity 58.5 ± 19.5 %. They recorded comparatively less larval, pre-pupal and pupal period i.e. 14.6, 3.1 and 11.6 and 12.3, 2.0 and 9.8 days during March and April, respectively with comparatively higher temperature 22.1 ± 7.6 and 26.8 ± 7.6 °C and less relative humidity 52.2 ± 21.5 and 46.0 ± 20.0 during these two months, respectively.

Bilapate (1988) investigated growth and development of *H. armigera* on different host plants in Marathwada, India. He recorded mean larval, pre-pupal and pupal period of 14.26, 1.46 and 14.59 days, respectively on chickpea.

Susceptibility of different hosts to *H. armigera* was studied by Goyal and Rathore (1988). They found that *H. armigera* larvae reared on chickpea leaves took 10.90, 1.90 and 9.44 days for completion of larval pre-pupal an pupal period, respectively.

Effects of different levels of constant temperature and humidity on the development and survival of *H. armigera* was studied by Sharma and Choudhary (1988). They found that larvae reared at 20 °C took 31.4 days to complete its larval stage. As compared to this it takes 19.31, 15.2 and 10.3 days to complete its larval stage at higher temperature i.e. 25, 30 and 35 °C, respectively.

Bajpai and Sehgal (1993) studied the oviposition performances, larval development and survival of *H. armigera* on chickpea and weed hosts at Pantnagar, India. They found that larvae reared on chickpea leaves at 29 ± 1 °C and 80 ± 5 % RH took 17.0 and 9.0 days to complete its larval and pupal stage, respectively.

Bio-ecology and reproductive potentiality of *H. armigera* on different host crops was studied by Valand and Patel (1993). Study revealed that, the larvae reared on gram at 21.65 ± 6.53 °C and 75.71 % RH took 30.00 days to complete its larval stage. Similarly it took 2.33 and 22.08 days to complete its pre-pupal and pupal period at 17.55 ± 4.24 °C and 71.6 % RH and 20.25 ± 2.85 and 71.05 %, respectively.

Verma *et al.* (1994) studied incidence, biology and population fluctuations of *H. armigera* in mid-hill region of Himachal Pradesh. They found that larvae reared on chickpea took 19.7 days to complete its larval period.

Bio-ecological studies on gram pod borers *Heliothis* spiecies under Jammu conditions were made by Thakur *et al.* (1995). They reported that, larval and pupal stages ranged from 15 to 25 and 9 to 15 days, respectively depending upon season and type of food.

Yoshida *et al.* (1995) studied the mechanism of resistance to *H. armigera* in chickpea. A feeding test using unwashed and washed chickpea leaves revealed that the substance responsible for the growth inhibition was water-soluble and present on the surface of leaves. Malic acid and oxalic acid were detected as major component of acid exudates of chickpea. The study further revealed that the oxalic acid had showed significant growth inhibition effect on larvae of *H. armigera* whereas malic acid showed no effect on larval growth.

Bhatt and Patel (2001) studied the biology of *H. armigera* on chickpea at room temperature. Their study revealed that the larvae produced six larval instars and took 20.60 ± 1.78 days to complete its larval stage. While the pupal stage lasted for 2.47 ± 0.70 days.

Kulkarni *et al.* (2004) had made comparative studies on the biology of *H. armigera* on different food substrates and recorded 12.70 and 13.77 days for completion of larval and pupal stage, respectively on chickpea.

Similarly, Surana *et al.* (2004) studied the host influence on developmental events of *H. armigera* and recorded 17.4, 3.00 and 14.50 days for completion of larval, pre-pupal and pupal period, respectively on chickpea.

CHAPTER – III

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

Because of the hazardous effects of chemical insecticides as well as their increasing cost, Biological Control is becoming popular component of an integrated pest management. Among various tools of biological pest suppression use of disease causing microorganisms is found effective in insect-pest control (Dhaliwal and Arora, 2001). The insecticides containing disease causing microorganisms as an active ingredient for control of insect-pest is called as microbial insecticides which are not only eco-friendly but can compatibly be incorporated in the integrated pest management programme. However, efficacy of such microbial insecticides either alone or in combination has been rarely evaluated against *Helicoverpa armigera* in chickpea.

Considering this, efforts have been made in the present investigations to test and evaluate different microbial insecticides, their judicious combinations and schedules for eco-friendly management of *H. armigera* in chickpea. At the same time studies on the biotic complex, population dynamics and effect of malic acid on larval and pupal development of *H. armigera* were also conducted.

The field experiments were conducted in the research field of Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during two consecutive post-rainy seasons of 2003-04 and 2004-05. Whereas, laboratory experiments were carried out in the PG laboratory during 2003-04 and 2004-05. The materials required and methods adopted are described below under different sub-headings.

3.1 MATERIALS

For conducting the present investigations, materials required like chickpea seeds, agricultural implements, fertilizers, bullock pair, knapsack sprayer, electronic balance, rearing equipments, chemical and microbial insecticides, malic acid etc. were provided by the Department of Agricultural Entomology.

Table 1: Details of microbial insecticides and other chemicals

Sr. No.	Insecticide	Formulation	Dosage / conc. used	Source of supply
1.	*Metarhizium anisopliae* (Bio-magic)	WP	2.5 kg / ha and 1.25 kg / ha	Indore Biotech Inputs and Research (Pvt) Ltd. 6, Sheekh Mohalla, Main Road, Indore 452007 (MP)
2.	*Beauveria bassiana* (Bio-Wonder)	WP	2.5 kg / ha and 1.25 kg / ha	Indore Biotech Inputs and Research (Pvt) Ltd. 6, Sheekh Mohalla, Main Road, Indore 452007 (MP)
3.	*Bacillus thuringiensis* (PDKV)	Liquid	750 ml/ ha and 375 ml/ ha	Department of Entomology, Dr. PDKV, Akola (M.S.)
4.	*Helicoverpa armigera* nuclear polyhedrosis virus	Liquid	250 LE/ha and 125 LE/ ha	Department of Entomology, Dr. PDKV, Akola (M.S.)
5.	Endosulfan (Endocel)	35 EC	0.06 %	Excel Industries Ltd., 184-187, Swami Vivekanand Road, Jogeshwari, Mumbai-400 102 (M.S.)
6.	Spinosad (Tracer)	45 SC	0.01 %	DE-NOCIL, Crop Protection Pvt Ltd., Unit no.1, first floor, Corporate Park, V.N. Purav marg, Chembur, Mumbai 400 071.

3.1.1 Rearing equipments for *H. armigera*

a) Plastic containers for larval rearing

It is made up of transparent plastic with 3.5 cm in diameter and 4.0 cm height with soft and coloured plastic lid. These were used for rearing *Helicoverpa* larvae individually for laboratory studies.

b) Mating and oviposition cage

This is rectangular wooden cage 30 X 30 X 60 cm having glass door suitable to observe the activities of adults and to provide sufficient light. Round opening with net sleeve on one side of cage is provided for food supply and other operations. It consisted of a sliding reversible window on bottom at right hand side to release the adults for mating and oviposition in the cage

3.2 METHODS

3.2.1 Field Studies

3.2.1.1 Evaluation of bio-efficacy of microbial insecticides alone and in combination

To evaluate the bio-efficacy of microbial insecticides alone and in combination with other microbial insecticides a field experiment was undertaken during two consecutive post-rainy seasons of 2003-04 and 2004-05. The plan of layout for the experiments is illustrated in figure 1. The layout was common during both seasons. The details of experiment are as follows.

Design of experiment	:	Randomized Block Design
Number of replications	:	3 (Three)
Number of treatments	:	12 (Twelve)
Gross Plot size	:	3.6 m X 4.0 m
Net plot size	:	3.0 m X 3.4 m
Spacing	:	30 X 10 cm

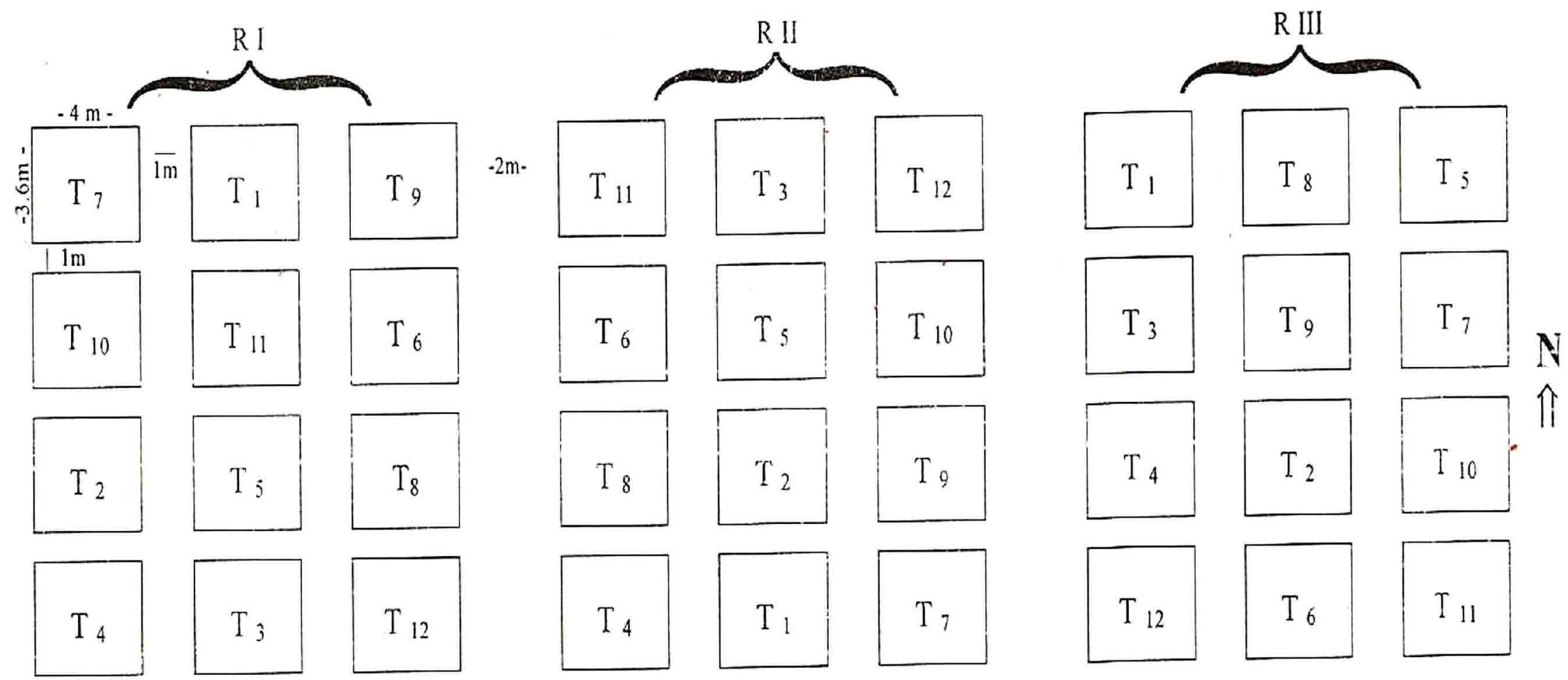

Figure 1 : **Plan of layout for evaluation of bio-efficacy of microbial insecticide alone and in combination**

T_1 - *Metarhizium anisopliae* @ 2.5 kg / ha

T_2 - *Beauveria bassiana* @ 2.5 kg / ha

T_3 - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha

T_4 - *Bacillus thuringiensis* (PDKV) @ 750 ml / ha

T_5 - *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha

T_6 - *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* (PDKV) @ 375 ml / ha

T_7 - *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha

T_8 - *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* (PDKV) @ 375 ml / ha

T_9 - *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE / ha + *Bacillus thuringiensis* (PDKV) @ 375 ml / ha

T_{10} - Endosulfan @ 0.06 %

T_{11} - spinosad @ 0.01 %

T_{12} - Untreated control

Interspace		
Between treatments	:	1.0 m
Between replications	:	2.0 m
Crop	:	Chickpea
Variety	:	Chaffa
Seed rate	:	55 kg / ha
No. of plants / gross plot	:	480
No. of plants / net plot	:	340
Total planted area	:	518.4 m^2
Fertilizer application	:	25 : 50 : 00 NPK kg / ha
Seed treatment	:	*Trichoderma* @ 4 gm / kg seeds
Date of sowing		
2003-04	:	06th October, 2003
2004-05	:	07th October, 2004

Details of treatments

T_1 - *Metarhizium anisopliae* (2.5 Kg/ha)

T_2 - *Beauveria bassiana* (2.5 Kg/ha)

T_3 - *Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)

T_4 - *Bacillus thuringiensis* (PDKV) (750 ml /ha)

T_5 - *Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)

T_6 - *Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)

T_7 - *Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)

T_8 - *Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)

T_9 - *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)

T_{10} - Endosulfan (0.06 %)

T_{11} - Spinosad (0.01 %)

T_{12} - Untreated control

3.2.1.2 Evaluation of different modules for bio-intensive management of *H. armigera* in chickpea

To evaluate different bio-intensive modules against *H. armigera* in chickpea a field experiment was undertaken during two consecutive post-rainy seasons of 2003-04 and 2004-05. The plan of layout is illustrated in figure 2. Same plan of layout was adopted during both *rabi* seasons. The details of experiment were as follows;

Design of experiment	:	Randomized Block Design
Number of replications	:	3 (Three)
Number of treatments	:	8 (Eight)
Gross Plot size	:	3.6 m X 4.0 m
Net plot size	:	3.0 m X 3.4 m
Spacing	:	30 X 10 cm
Interspace		
Between treatments	:	1.0 m
Between replications	:	2.0 m
Crop	:	Chickpea
Variety	:	Chaffa
Seed rate	:	55 kg / ha
No. of plants / gross plot	:	480
No. of plants / net plot	:	340
Total planted area	:	345.6 m^2
Fertilizer application	:	25 : 50 : 00 NPK kg / ha
Seed treatment	:	Trichoderma @ 4 gm / kg seeds
Date of sowing		
2003-04	:	13^{th} October, 2003
2004-05	:	07^{th} October, 2004

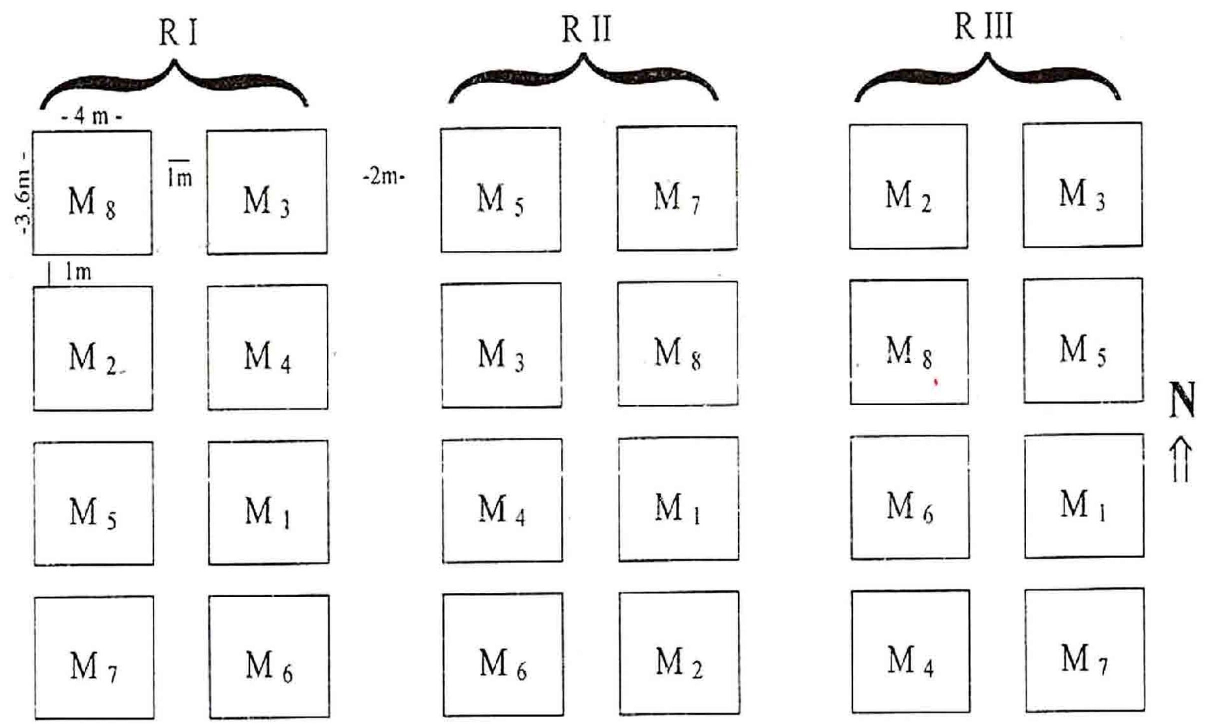

Figure 2 : **Plan of layout for evaluation of different modules for bio-intensive management of *H. armigera* on chickpea**

M 1 : *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha

M 2 : *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %

M 3 : Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha

M 4 : Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha -

M 5 : *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad @ 0.01 %

M 6 : Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha

M 7 : Endosulfan @ 0.06 % (3 sprays)

M 0 : Untreated control

Details of modules

M_1 - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha.

M_2 - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %

M_3 - Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha

M_4 - Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha

M_5 - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad 50 g a.i. / ha

M_6 - Spinosad @ 50 g a.i. / ha - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha

M_7 - Three sprays of Endosulfan @ 0.06 %.

M_0 - Untreated Control

3.2.1.3 Preparation of 5 % NSKE

Recommended procedure was followed for preparation of 5% Neem Seed Kernel Extract (Annonymous, 2005). Accordingly, 5 kg of dried neem seeds were taken and made into fine powder and soaked in 9 liters of water over night. After 24 hours, the extract was decanted through cloth to which 200 gm of soap solution, separately prepared in 1 litre of water was added and then the final volume was made up to 100 liters by adding water.

3.2.1.4 Cultural operations

During 2003-04 and 2004-05, field was well prepared by repeated ploughing and harrowings. Plots were laid out as per design. Seeds were treated with *Trichoderma* as per recommendation. Beds were then seeded at a specific spacing by hand dibbling. Recommended doses of fertilizers were given at the time of sowing before irrigation. Gap filling was done whenever necessary for maintaining uniform plant population. Inter-culture operations and subsequent irrigations were applied as and when required.

3.2.1.5 Preparation of spray mixture

For preparation of spray mixture, the quantity of insecticide required per plot was calculated. Then the quantity of water required for spraying single plot, was calculated by actual spraying the plot with water. Thus, accordingly the spray mixture is prepared fresh every time by mixing calculated quantity of insecticides in required quantity of water.

3.2.1.6 Application of spray mixture

Spray mixture was applied with knapsack sprayer. Spraying was done in the morning. After application of each treatment, sprayer was thoroughly cleaned and again flushed with water to remove traces of previous insecticide applied.

The treatment sprayings were undertaken when larval population reached economic thresh-hold level and subsequent sprays were applied at 15 days intervals. According to Nimbalkar (2001) the population level of two larvae per meter row length was considered to undertake spray application. Accordingly, application of spray mixture for both the experiments and during both the seasons were undertaken on the following dates ;

Experiment - I

	2003-04	2004-05
First spray	19.11.2003	29.11.2004
Second spray	03.12.2003	13.12.2004

Experiment - II

	2003-04	2004-05
First spray	17.11.2003	08.11.2004
Second spray	01.12.2003	22.11.2004
Third spray	15.12.2003	06.12.2004

3.2.1.7 Method of recording observations

a) Observation on larval count

After application of each treatment larval count was taken on 10 randomly selected plants from each plot at 3, 7, 10 and 14 days.

b) Post harvest observation

The yield of chickpea grains (kg) was recorded from each net plot after harvesting, drying and threshing.

3.2.1.8 Population dynamics of *Helicoverpa armigera*

Population dynamics of *H. armigera* in chickpea was studied during two consecutive post-rainy seasons. For which separate plot of 10 X 10 m^2 dimension was sown on 13th October 2003 and 7th October 2004. Larval count was taken on ten randomly selected plants, from these plots at weekly intervals. Correlations were worked out with biotic and abiotic factors of environment.

3.2.2 Laboratory studies

Along with above field trials two laboratory experiments were also conducted to study biotic complex and effect of malic acid on larval and pupal development of *H. armigera*

3.2.2.1 Biotic complex of *H. armigera* in gram ecosystem

Twenty-five eggs and larvae of *H. armigera* were collected from the separately sown plot (10 X 10 m^2) at weekly interval. They were kept individually in plastic containers. Eggs were kept till hatching while larvae were reared till the adult stage. They were observed daily for the emergence of parasitoids.

3.2.2.2 Effect of malic acid on larval and pupal development of gram pod borer

Eggs of *H. armigera* were collected from the laboratory reared and mated *H. armigera* adults and kept for hatching. Newly hatched *H. armigera* larvae were put individually in plastic containers. They were grouped into three groups of ten larvae each. First group of larvae was reared on malic acid fortified chickpea leaves, second group was reared on water washed chickpea leaves while third group was reared on untreated chickpea leaves.

For this, chickpea leaves were brought daily from separately sown plot of 10 X 10 m^2. They were dipped in solution of 3 % malic acid and also in water for 5 minutes. They were then soaked in shade and then used for feeding. Observations on larval and pupal periods were recorded.

3.3 STATISTICAL ANALYSIS

In case of field studies to evaluate microbial pesticides alone or in combination and to evaluate different bio-intensive modules for management of *H. armigera*, the data on the larval population of *H. armigera* was transformed by appropriate transformations. The data, thus obtained along with yield data were tested for their statistical significance (Gomez and Gomez, 1984). Similarly pooled analysis for both the experiments were also carried out for two years field data.

The data on larval population, field parasitization and weather parameters were subjected to analysis to find out co-relation coefficients between them.

In case of studies on effect of malic acid on larval and pupal development of *H. armigera,* means and standard deviations were worked out and data were further analyzed by completely randomized design (Gomez and Gomez, 1984) to compare the significance of different feeding methods.

3.5 METEOROLOGICAL DATA

Weekly meteorological data for a period during which the field studies were carried out were obtained from the agro-meteorological observatory, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola(Appendix - A)

CHAPTER – IV

EXPERIMENTAL FINDINGS

CHAPTER – IV

EXPERIMENTAL FINDINGS

Field experiments were conducted during the present investigation to test the efficacy of microbial pesticides either alone or in combination and in scheduled applications for bio-intensive management of *H. armigera* in gram. Along with this, attempts were also made to generate information on seasonal incidence of this pest, biotic complex and effect of malic acid on it's larval and pupal development. Tha data and results obtained are illustrated through Tables 2 to 21, figures 3 to 9 and described under appropriate headings in the foregoing pages.

4.1 Evaluation of microbial insecticides either alone or in combination

4.1.1. Effect of various treatments on larval population on *H. armigera* during 2003-2004

4.1.1.1 Larval population of *H. armigera*, three days after first spray (2003-04)

Data on larval population of *H. armigera* three days after first spray obtained during 2003-2004 are presented in Table 2. All the treatments registered significantly lower larval population than untreated control. Spinosad @ 0.01 % recorded least larval population (1 larva / ten plants) followed by Endosulfan @ 0.06 % (1.33 larvae / ten plants). Both these treatments were at par and statistically superior over remaining treatments.

Next group of treatments in order of their efficacy were *Bacillus thuringiensis* @ 750 ml / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha, *Metarhizium anisopliae* @ 1.25 kg / ha +

Helicoverpa armigera nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha which were at par with each other and registered 3.00, 3.00, 3.33, 3.33, 3.67, 3.67, 3.67, 4.00 and 4.00 larvae / ten plants respectively. An untreated control had registered highest larval population of 5.67 / ten plants.

4.1.1.2 Larval population of *H. armigera* seven days after first spray (2003-04)

Data on larval population of *H. armigera* seven days after first spray, presented in Table 2 reveled significantly lower larval population in all the treatments than control. Among various treatments spinosad @ 0.01 % and endosulfan @ 0.06 % recorded significantly lowest larval population i.e. 0.67 and 1.00 larva / ten plants, respectively. It was followed by the treatment with *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha (2.00 larvae / ten plants) which was at par with endosulfan @ 0.06 %.

Another group of effective treatments in order of their merit were *Bacillus thuringiensis* @ 750 ml / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha which recorded 2.33, 2.67, 3.00, 3.00 and 3.33 larvae per ten plants, respectively.

Another treatments in order of their efficacy were *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, registered larval population of 3.67, 4.00 and 4.00 per ten plants respectively. Untreated control had 6.33 larvae per ten plants.

4.1.1.3 Larval population of *H. armigera*, ten days after first spray (2003-04)

Data (Table 2) on larval population of *H. armigera* ten days after first spray revealed significant superiority of all the treatments over control. Amongst various treatments, spinosad @ 0.01 % and endosulfan @ 0.06 % proved most effective (0.67 larva per ten plants) and significantly superior over rest of the treatments. Next group of effective treatments in order of merit were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Bacillus thuringiensis* @ 750 ml / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha which recorded 1.67, 2.00, 2.00, 2.33 and 2.33 larvae on ten plants, respectively. However, *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha was at par with endosulfan 0.06 %. Later two treatments were found at par with *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and recorded 3.33, 3.33, 3.33 and 3.67 larvae on ten plants respectively.

4.1.1.4 Larval population of *H. armigera*, fourteen days after first spray (2003-04)

Data on larval population of *H. armigera* fourteen days after first spray (Table 2) revealed significant differences amongst the various treatments. All the treatments proved significantly superior to untreated control. Spinosad @ 0.01 % was best in reducing larval population (1.67 larvae per ten plants) followed by endosulfan @ 0.06 % (2.00 larvae per ten plants) which were at par with each other. However, the later treatment was at par with *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha (3.00 larvae per ten plants). Treatment with *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha was followed by *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha, *Bacillus thuringiensis* @ 750 ml / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha were at par and they recorded 3.33, 3.67, 3.67 and 4.00 larvae per ten plants, respectively. Remaining treatments viz., *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were less effective and had recorded 4.67, 4.67, 5.00, and 5.33 larvae per ten plants, respectively. Untreated control had larval population of 7.33 per ten plants.

4.1.1.5 Larval population of *H. armigera*, three days after second spray (2003-04)

Data on larval population of *H. armigera* three days after second spray tabulated in Table 3 indicated significantly lower larval population in all the treatments than untreated control. Significantly lowest larval population was recorded in treatment with spinosad @ 0.01 % (0.67 larvae per ten plants) which did not differ significantly from treatment with endosulfan @ 0.06 % (1.00 larvae per ten plants).

Table 2 : Effect of various treatments on larval population of *H. armigera* at 3, 7, 10 and 14 days after first spray during 2003-04

Treat-ment No.	Treatment	Average larval population of *H. armigera* / ten plants			
		3 days after spraying	7 days after spraying	10 days after spraying	14 days after spraying
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	3.33 (1.82)	3.00 (1.86)	2.00 (1.58)	3.33 (1.82)
T_2	*Beauveria bassiana* (2.5 Kg/ha)	3.67 (1.90)	3.00 (1.86)	2.33 (1.68)	3.67 (1.90)
T_3	*Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	3.00 (1.73)	2.00 (1.58)	1.67 (1.46)	3.00 (1.72)
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	3.00 (1.72)	2.33 (1.68)	2.00 (1.56)	3.67 (1.91)
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	3.67 (1.91)	3.33 (1.95)	3.33 (1.95)	4.67 (2.16)
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	3.67 (1.91)	4.00 (2.11)	3.33 (1.95)	5.00 (2.24)
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	4.00 (1.99)	3.67 (2.03)	3.33 (1.95)	4.67 (2.12)
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	4.00 (1.99)	4.00 (2.12)	3.67 (2.04)	5.33 (2.31)
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	3.33 (1.82)	2.67 (1.77)	2.33 (1.68)	4.00 (1.99)
T_{10}	Endosulfan (0.06 %)	1.33 (1.14)	1.00 (1.17)	0.67 (1.05)	2.00 (1.38)
T_{11}	Spinosad (0.01 %)	1.00 (1.00)	0.67 (1.05)	0.67 (1.00)	1.67 (1.28)
T_{12}	Untreated control	5.67 (2.38)	6.33 (2.61)	7.00 (2.73)	7.33 (2.71)
	'F'test	Sig.	Sig.	Sig.	Sig.
	S.E. (m) ±	0.11	0.14	0.14	0.13
	C.D. at 5%	0.33	0.41	0.41	0.37
	C.V. (%)	11.07	13.36	14.06	11.18

* Figures in parentheses are corresponding square root transformed values

Next effective group of treatments were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / Ha, *Bacillus thuringiensis* @ 750 ml / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @ 2.5 kg / ha and *Beauveria bassiana* @ 2.5 kg / ha which recorded 2.33, 2.67, 3.00, 3.00 and 3.33 larvae on ten plants, respectively. Treatments *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha were least effective and recorded 4.33, 4.33, 4.67 and 4.67 larvae on ten plants, respectively.

4.1.1.6 Larval population of *H. armigera*, seven days after second spray (2003-04)

Data in Table 3 on larval population of *H. armigera* seven days after second spray showed significant differences amongst various treatments. All the treatments recorded significantly lower larval population than untreated control. Amongst various treatments spinosad @ 0.01 % and endosulfan @ 0.06 % proved their superiority in reducing larval population. Both these treatments recorded 0.33 larvae on ten plants and were significantly superior over rest of the treatments. These treatments were followed by *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Bacillus thuringiensis* @ 750 ml / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Metarhizium anisopliae* @ 2.5 kg / ha which were at par with each other and recorded 1.67, 2.33, 2.67 and 2.67 larvae on ten plants, respectively. Remaining treatments viz., *Beauveria bassiana* @ 2.5 kg / ha, *Metarhizium* *anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were less effective and recorded 3.00, 3.67, 4.00, 4.33 and 4.33 larvae on ten plants, respectively. Untreated control registered highest of 6.33 larvae on ten plants.

4.1.1.7 Larval population of *H. armigera*, ten days after second spray (2003-04)

It is seen from the Data (Table 3) on larval population of *H. armigera* ten days after second spray that the treatments exhibited significant differences and all the treatments evaluated proved significantly superior in reducing larval numbers over untreated control. However, amongst various treatments spinosad @ 0.01 % and endosulfan @ 0.06 % were most effective treatments with 0.33 larvae per ten plants. These treatments were followed by *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Bacillus thuringiensis* @ 750 ml / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 1.25 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha which recorded 1.33, 1.67, 2.00, 2.00 and 2.33 larvae per ten plants, respectively and were at par with each other. *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha and *Bacillus thuringiensis* @ 375 ml / ha were at par with each other and recorded 3.00, 3.33, 3.33 and 4.00 larvae per ten plants, respectively. Untreated plots registered highest of 6.00 larvae per ten plants.

4.1.1.8 Larval population of *H. armigera*, fourteen days after second spray (2003-04)

Data presented in Table 3 on larval population of *H. armigera* fourteen days after second spray were significant. All the treatments were effective in lowering the larval population over untreated control. spinosad @ 0.01 % was most effective (0.00 larvae per ten plants) followed by endosulfan @ 0.06 % (0.33 larvae per ten plants) which were at par with each other.

Helicoverpa armigera nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @ 2.5 kg / ha both with 1.33 larvae per ten plants and *Beauveria bassiana* @ 2.5 kg / ha (2.00 larvae per ten plants) formed the second group of effective treatments.

Third group of better treatment comprised of *Bacillus thuringiensis* @ 750 ml / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha which registered larval population of 2.33, 2.33, 2.67 and 3.00 per ten plants, respectively and were at par with each other. Remaining treatments in order of their efficacy were *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha with 3.33 and 3.67 larvae per ten plants as against highest of 6.00 larvae on ten plants recorded in untreated control plants.

Table 3 : Effect of various treatments on larval population of *H. armigera* at 3, 7, 10 and 14 days after second spray during 2003-04

Treatment No.	Treatment	Average larval population of *H. armigera* / ten plants			
		3 days after spraying	7 days after spraying	10 days after spraying	14 days after spraying
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	3.00 (1.86)	2.67 (1.77)	1.67 (1.46)	1.33 (1.34)
T_2	*Beauveria bassiana* (2.5 Kg/ha)	3.33 (1.95)	3.00 (1.86)	2.00 (1.58)	2.00 (1.58)
T_3	*Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	2.33 (1.68)	1.67 (1.46)	1.33 (1.34)	1.33 (1.34)
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	2.67 (1.77)	2.33 (1.68)	2.00 (1.56)	2.33 (1.68)
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	4.33 (2.20)	3.67 (2.04)	3.00 (1.86)	2.67 (1.77)
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	4.67 (2.27)	4.33 (2.20)	3.33 (1.95)	3.33 (1.95)
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	4.33 (2.20)	4.00 (2.11)	3.33 (1.95)	3.00 (1.86)
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	4.67 (2.26)	4.33 (2.20)	4.00 (2.11)	3.67 (2.04)
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	3.00 (1.86)	2.67 (1.77)	2.33 (1.68)	2.33 (1.68)
T_{10}	Endosulfan (0.06 %)	1.00 (1.17)	0.33 (0.88)	0.33 (0.88)	0.33 (0.88)
T_{11}	Spinosad (0.01 %)	0.67 (1.05)	0.33 (0.88)	0.33 (0.88)	0.00 (0.71)
T_{12}	Untreated control	7.00 (2.73)	6.33 (2.61)	6.00 (2.54)	6.00 (2.55)
	'F'test	Sig.	Sig.	Sig.	Sig.
	S.E. (m) $\pm$	0.14	0.12	0.13	0.11
	C.D. at 5%	0.41	0.36	0.39	0.31
	C.V. (%)	12.54	11.88	14.00	11.36

* Figures in parentheses are corresponding square root transformed values

4.1.2 Effect of various treatment on grain yield of chickpea during 2003-04

The data on grain yield of chickpea as influenced by various treatments are presented in Table 4. All the treatments produced significantly higher grain yield than untreated control. Treatment with spinosad @ 0.01 % recorded highest grain yield (16.27 q / ha) and did not differ significantly from endosulfan @ 0.06 % (15.88 q / ha).

Next group of better treatment included *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha (14.51 q / ha), *Bacillus thuringiensis* @ 750 ml / ha (14.31 q / ha), *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha (14.02 q / ha) and *Metarhizium anisopliae* @ 2.5 kg / ha (13.92 q / ha) which were at par. These treatments except former one did not differ significantly from *Beauveria bassiana* @ 2.5 kg / ha (13.72 q / ha).

Treatments with *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg /ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha produced comparatively lower grain yield i.e. 12.16, 11.86, 11.76 and 11.08 q / ha receptively. An untreated control yielded 10.20 q / ha grains.

4.1.3 Incremental cost benefit ratio of various treatments during 2003-04

Data presented in Table 4 (Appendix - B) revealed that, treatment with endosulfan @ 0.06 % emerged as the most economically viable treatment giving highest ICBR of 1 : 7.45 followed by *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha (1 : 4.07). These two treatments were followed by

Table 4 : Effect of various treatments on grain yield of chickpea and incremental cost benefit ratio during 2003-04

Treatment No.	Treatment	Mean yield (q / ha)	ICBR	Rank
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	13.92	1 : 1.70	7
T_2	*Beauveria bassiana* (2.5 Kg/ha)	13.72	1 : 1.76	6
T_3	*Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	14.51	1 : 4.07	2
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	14.31	1 : 3.31	4
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	12.16	1 : 1.17	8
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	11.76	1 : 0.88	10
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	11.86	1 : 1.09	9
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	11.08	1 : 0.54	11
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	14.02	1 : 3.32	3
T_{10}	Endosulfan (0.06 %)	15.88	1 : 7.45	1
T_{11}	Spinosad (0.01 %)	16.27	1 : 2.68	5
T_{12}	Untreated control	10.20	--	--
	'F'test	Sig.		
	S.E. (m) ±	0.26		
	C.D. at 5%	0.78		
	C.V. (%)	3.43		

Helicoverpa armigera nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thruringiensis* @ 375 ml / ha, *Bacillus thringiensis* @ 750 ml / ha, spinosad@ 0.01 %, *Beauveria bassiana* @ 2.5 kg / ha and *Metarhizium anisopliae* @ 2.5 kg / ha with ICBR of 1 : 3.32, 1 : 3.31, 1 : 2.68, 1 : 1.76, and 1 : 1.70, respectively.

The treatment combination viz., *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thringiensis* @ 375 ml / ha were found comparatively less economical as exhibited ICBR of 1 : 1.17, 1 : 1.09, 1 : 0.88 and 1 : 0.54, respectively.

4.1.4 Effect of various treatments on larval population of *H. armigera* during 2004-05

4.1.4.1 Larval population of *H. armigera*, three days after first spray (2004-05)

Larval population of *H. armigera* three days after first spray (Table 5) revealed significant differences amongst the various treatments. All the treatments were significantly superior over untreated control. Among various treatments endosulfan @ 0.06 % and spinosad @ 0.01 % recorded lowest larval population i.e. 2.67 larvae per ten plants and were superior over rest of the treatments.

The next effective treatments in order of merit were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Bacillus thuringiensis* @ 750 ml / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa* *armigera* nuclear polyhedrosis virus @ 125 LE / ha which were at par with each other and recorded 4.33, 4.67, 5.33, 5.33, 5.67 and 5.67 larvae on ten plants respectively. Remaining three treatments viz., *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were less effective and all have recorded six larvae per ten plants. Untreated plots had highest of 8.33 larval population per ten plants.

4.1.4.2 Larval population of *H. armigera*, seven days after first spray (2004-05)

Data in Table 5 revealed that all the treatments significantly reduced the larval population of *H. armigera* over control. However, spinosad @ 0.01 % has proved its superiority by recording least larval population (1.67 per ten plants) and was at par with endosulfan @ 0.06 % (2.00 larvae per ten plants)

Treatments *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Bacillus thuringiensis* @ 750 ml / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* 375 ml / ha recorded 3.67, 4.33 and 4.67 larvae per ten plants receptively and were at par with each other. Later two treatments however were again found at par with *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha which recorded 5.00, 5.67, 5.67 and 5.67 larvae per ten plants, respectively. Remaining two treatments *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were less effective having 6.00 larvae per ten plants as against highest of 8.00 larvae per ten plants recorded in untreated control.

4.1.4.3 Larval population of *H. armigera*, ten days after first spray (2004-05)

Larval population of *H. armigera* in various treatments ten days after first spray are presented in Table 5. Significant differences were observed within the treatments and all the treatments registered significantly lower larval population over untreated control. Spinosad @ 0.01 % was most effective followed by endosulfan @ 0.06 % which recorded 1.33 and 1.67 larvae per ten plants respectively and were at par with each other.

Above treatments were followed by *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha, *Bacillus thuringiensis* @ 750 ml / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 325 LE / ha, recording 3.00, 3.67, 4.00, 4.00 and 4.33 larvae per ten plants, respectively. Remaining four treatments viz., *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were less effective and recorded 5.00, 5.33, 5.33 and 5.67 larvae per ten plants, respectively. Significantly higest (8.00 per ten plants) larval population were registered in plots which were not treated.

4.1.4.4 Larval population of *H. armigera*, fourteen days after first spray (2004-05)

It is seen from the data on larval population of *H. armigera* fourteen days after first spray (Table 5) that the treatments exhibited significant

Table 5 : Effect of various treatments on larval population of *H. armigera* at 3, 7, 10 and 14 days after first spray during 2004-05

Treat-ment No.	Treatment	Average larval population of *H. armigera* / ten plants			
		3 days after spraying	7 days after spraying	10 days after spraying	14 days after spraying
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	5.33 (2.31)	5.00 (2.23)	3.67 (1.90)	4.33 (2.08)
T_2	*Beauveria bassiana* (2.5 Kg/ha)	5.67 (2.38)	5.67 (2.38)	4.00 (1.99)	4.67 (2.16)
T_3	*Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	4.33 (2.08)	3.67 (1.91)	3.00 (1.72)	4.00 (1.99)
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	4.67 (2.16)	4.33 (2.08)	4.00 (2.00)	4.67 (2.16)
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	5.67 (2.38)	5.67 (2.38)	5.00 (2.23)	5.33 (2.31)
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	6.00 (2.44)	6.00 (2.45)	5.33 (2.29)	5.67 (2.37)
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	6.00 (2.43)	5.67 (2.37)	5.33 (2.31)	5.67 (2.38)
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	6.00 (2.45)	6.00 (2.44)	5.67 (2.38)	5.67 (2.38)
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	5.33 (2.31)	4.67 (2.15)	4.33 (2.08)	5.00 (2.24)
T_{10}	Endosulfan (0.06 %)	2.67 (1.61)	2.00 (1.38)	1.67 (1.28)	2.33 (1.52)
T_{11}	Spinosad (0.01 %)	2.67 (1.63)	1.67 (1.28)	1.33 (1.14)	2.00 (1.38)
T_{12}	Untreated control	8.00 (2.82)	8.33 (2.89)	8.00 (2.83)	8.00 (2.83)
	'F'test	Sig.	Sig.	Sig.	Sig.
	S.E. (m) ±	0.11	0.10	0.12	0.10
	C.D. at 5%	0.32	0.31	0.36	0.29
	C.V. (%)	8.33	8.40	10.50	7.94

* Figures in parentheses are corresponding square root transformed values

differences and all the treatments significantly reduced the larval population over control. Treatments spinosad @ 0.01 % and endosulfan @ 0.06 % proved most effective and reduced larval population upto 2.00 and 2.33 larvae per ten plants, respectively and were also statistically at par.

Next effective treatments in order of their efficacy were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha, *Bacillus thuringiensis* @ 750 ml / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha which recorded 4.00, 4.33, 4.67, 4.67 and 5.00 larvae per ten plants, respectively. Remaining four treatments viz., *Metarhizium anisopliae* @1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE / ha, *Metarhizium anisopliae* @1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Beauveria bassiana* @1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE / ha and *Beauveria bassiana* @125 kg / ha + *Bacillus thuringiensis* @375 ml / ha recorded 5.33, 5.67,5.67 and 5.67 larvae per ten plants, respectively. Untreated control registered highest larval population (8.00 per ten plants).

4.1.4.5 Larval population of *H. armigera*, three days after second spray (2004-05)

Data on larval population of *H. armigera* three days after second spray (Table 6) showed significantly lower population in all the treatments than untreated control. Amongst various treatments spinosad @ 0.01 % recorded least population (1 larvae on ten plants) and was at par with endosulfan @ 0.06 % (1.33 larvae per ten plants). These two treatments were followed by *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha (3 larvae per ten plants) and *Bacillus thuringiensis* @ 750 ml / ha (3.33 larvae per ten plants) which were at par with each other. The later treatment was also at par with *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @375 ml / ha all of which recorded 4.33 larvae per ten plants. Treatments, *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Beauveria bassiana* @1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were superior over control had recorded 5.00, 5.33, 5.33 and 5.67 larvae on ten plants, respectively. Highest larval population of 7.67 on every ten plants was registered in untreated plots.

4.1.4.6 Larval population of *H. armigera*, seven days after second spray (2004-05)

Larval population of *H. armigera* seven days after second spray (Table 6) clearly indicates significant differences amongst various treatments. All the treatments were significantly superior over control in reducing the larval population. Spraying of spinosad @ 0.01 % and endosulfan @ 0.06 % were most effective with 0.67 larvae per ten plants. These two treatments were followed by *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha (2 larvae per ten plants) and *Bacillus thuringiensis* @ 750 ml / ha (2.67 larvae per ten plants) which were at par with each other. Later treatment however, did not differ significantly from *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Metarhizium anisopliae* @ 2.5 kg / ha which recorded 3.33 and 3.67 larvae per ten plants.

Treatment with *Beauveria bassiana* @ 2.5 kg / ha was moderately effective and recorded 4.00 larvae on ten plants and did not differ significantly from

Metarhizium anisopliae @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha which recorded 4.67, 5.00 and 5.00 larvae per ten plants, respectively. Treatments *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha recorded higher population (5.33 larvae per ten plants) but was superior over control (7.67 larvae per ten plants)

4.1.4.7 Larval population of *H. armigera*, ten days after second spray (2004-05)

It is reveled from the data of larval population of *H. armigera* ten days after second spray (Table 6) that there were significant differences amongst various treatments. All the treatments proved significantly superior to untreated control. Amongst various treatments, spinosad @ 0.01 % (0.33 larvae per ten plants) and endosulfan @ 0.06 % (0.67 larvae per ten plants) were proved most effective and did not differ with each other.

These treatments were followed by *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha, *Bacillus thuringiensis* @ 750 ml / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha which recorded 1.67, 2.00, 2.33, 2.33 and 2.67 larvae per ten plants, respectively. Later treatment however did not differ statistically from *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha (4 larvae per ten plants) which was also statistically at par with *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 LE / ha, *Beauveria bassiana* @ 1.25 kg /ha + *Helicoverpa* *armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, and all these recorded 4.33 larvae per ten plants. Maximum larvae per ten plants were registered in plots receiving no treatments.

4.1.4.8 Larval population of *H. armigera*, fourteen days after second spray (2004-05)

Population of *H. armigera* larvae fourteen days after second spray are presented in Table 6 indicated significantly lower number of larvae in all the treatments than untreated control. Treatments with spinosad @ 0.01 % and endosulfan @ 0.06 % recorded least larval population i.e. 0.33 and 1.00 larvae on ten plants, respectively which were at par. Next group of better treatments included *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Bacillus thuringiensis* @ 750 ml / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha which recorded 2.00, 2.33, 2.67, 2.67 and 3.00 larvae per ten plants, respectively and were statistically equal in effect. Later three treatments do not differ statistically from *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, both recorded 4.00 larvae on ten plants. Remaining two treatments viz., *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha each recorded 4.33 larvae on ten plants and were superior over control (6.67 larvae per ten plants).

Table 6 : Effect of various treatments on larval population of *H. armigera* at 3, 7, 10 and 14 days after second spray during 2004-05

Treat-ment No.	Treatment	Average larval population of *H. armigera* / ten plants			
		3 days after spraying	7 days after spraying	10 days after spraying	14 days after spraying
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	4.33 (2.08)	3.67 (2.04)	2.00 (1.56)	2.33 (1.68)
T_2	*Beauveria bassiana* (2.5 Kg/ha)	4.33 (2.08)	4.00 (2.11)	2.33 (1.68)	2.67 (1.77)
T_3	*Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	3.00 (1.72)	2.00 (1.58)	1.67 (1.46)	2.00 (1.56)
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	3.33 (1.79)	2.67 (1.77)	2.33 (1.68)	2.67 (1.76)
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	5.00 (2.23)	4.67 (2.27)	4.00 (2.11)	4.00 (2.11)
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	5.33 (2.31)	5.00 (2.34)	4.33 (2.19)	4.33 (2.20)
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	5.33 (2.31)	5.00 (2.34)	4.33 (2.20)	4.00 (2.11)
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	5.67 (2.38)	5.33 (2.41)	4.33 (2.20)	4.33 (2.20)
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	4.33 (2.08)	3.33 (1.95)	2.67 (1.76)	3.00 (1.86)
T_{10}	Endosulfan (0.06 %)	1.33 (1.14)	0.67 (1.05)	0.67 (1.05)	1.00 (1.17)
T_{11}	Spinosad (0.01 %)	1.00 (1.00)	0.67 (1.05)	0.33 (0.88)	0.33 (0.88)
T_{12}	Untreated control	7.67 (2.77)	7.67 (2.85)	7.00 (2.73)	6.67 (2.67)
	'F'test	Sig.	Sig.	Sig.	Sig.
	S.E. (m) ±	0.11	0.09	0.13	0.16
	C.D. at 5%	0.31	0.27	0.39	0.46
	C.V. (%)	9.33	8.11	12.98	14.72

* Figures in parentheses are corresponding square root transformed values

4.1.5 Effect of various treatments on grain yield of chickpea during 2004 - 05

Data on grain yield as influenced by various treatments are presented in Table 7. All treatments evaluated produced significantly higher grain yield than untreated control. Among various treatments, spinosad @ 0.01 % and endosulfan @ 0.06 % proved best and recorded at par grain yield of 14.90 q / ha and 14.41 q / ha, respectively. Next group of better treatments in order of merit were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha (12.94 q / ha), *Bacillus thuringiensis* @ 750 ml / ha (12.64 q / ha) and *Helicoverpa armigera* nuclear polyhedrosis virus 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha (12.55 q / ha) and *Metarhizium anisopliae* @ 2.5 kg / ha (12.06 q / ha) which were at par.

However, the later treatment was at par with *Beauveria bassiana* @ 2.5 kg / ha and *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha which was moderately effective and produced 11.76 and 11.12 q / ha, grain yield, respectively. Treatments *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE/ ha (10.69 q / ha), *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @375 ml / ha (10.39 q / ha) and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha (10.19 q / ha) produced comparatively less grain yield but were better than untreated control (9.12 q / ha).

4.1.6 Incremental cost benefit ratio of various treatments during 2004-05

Data from Table 7 (Appendix C) indicate that, treatment with endosulfan @0.06 % exhibited highest incremental cost benefit ratio (1 : 6.29) and proved to be most economical tratment amongst all.

Table 7 : Effect of various treatments on grain yield of chickpea and incremental cost benefit ratio during 2004-05

Treatment No.	Treatment	Mean yield (q / ha)	ICBR	Rank
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	12.06	1 : 1.17	7
T_2	*Beauveria bassiana* (2.5 Kg/ha)	11.76	1 : 1.20	6
T_3	*Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	12.94	1 : 3.27	2
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	12.64	1 : 2.57	4
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	11.12	1 : 1.09	8
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	10.39	1 : 0.65	10
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	10.69	1 : 0.93	9
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	10.19	1 : 0.60	11
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	12.55	1 : 2.70	3
T_{10}	Endosulfan (0.06 %)	14.41	1 : 6.29	1
T_{11}	Spinosad (0.01 %)	14.90	1 : 2.31	5
T_{12}	Untreated control	09.12	--	--
	'F'test	Sig.		
	S.E. (m) ±	0.33		
	C.D. at 5%	0.97		
	C.V. (%)	4.81		

The next treatments in order were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha (1 : 3.27), *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thringiensis* @ 375 ml / ha (1 : 2.70) *Bacillus thringiensis* @ 750 ml / ha (1 : 2.57), spinosad @ 0.01 %, (1 : 2.31), *Beauveria bassiana* @ 2.5 kg / ha (1 : 1.20) and *Metarhizium anisopliae* @ 2.5 kg / ha (1 : 1.17).

Treatments viz., *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE /ha, *Beauveria bassiana* @ 1.25 LE / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thringiensis* @ 375 ml / ha were observed less economical and registered ICBR of 1 : 1.09, 1 : 0.93, 1 : 0.65 and 1 : 0.60, respectively.

4.1.7 Effect of various treatments on larval population of *H. armigera* (Pooled)

4.1.7.1 Larval population of *H. armigera*, three days after first spray (Pooled)

Two year's pooled data on larval population of *H. armigera* three days after first spray are presented in Table 8 and illustrated graphically in figure 3. It revealed superiority in all the treatments over control in reducing larval population. Amongst various treatments spinosad @ 0.01 % and endosulfan @ 0.06 % were most effective and reduced larvae upto 1.83 and 2.00 per ten plants, respectively.

Next group of effective treatments in order of their efficacy were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Bacillus thuringiensis* @ 750 ml / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @375 ml / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Metarhizium anisopliae*

@1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha which recorded 3.67, 3.83, 4.33,4.33, 4.67 and 4.67 larvae on ten plants, respectively. Remaining three treatments viz., *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were less effective and recorded 4.83, 5.00 and 5.00 larvae on ten plants, respectively as against higher larval population recorded (6.83 per ten plants) in plots receiving no treatments.

4.1.7.2 Larval population of *H. armigera*, seven days after first spray (Pooled)

Larval population of *H. armigera* seven days after first spray based on two year's pooled results(Table 8 , figure 3) revealed significant differences within the treatments and all the treatments proved significantly superior over control. Treatment with spinosad @ 0.01 % recorded lowest population (1.17 larvae per ten plants) which were at par with endosulfan @ 0.06 % (1.50 larvae per ten plants) and both were significantly superior to rest of the treatments.

Group of next effective treatments comprised, *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Bacillus thuringiensis* @ 750 ml / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha which recorded 2.83, 3.33 and 3.67 larvae on ten plants, respectively and were statistically at par in their effectiveness. Later treatments was also at par with *Metarhizium anisopliae* @2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha which recorded 4.00, 4.33 and 4.50 larvae per ten plants, respectively. Treatments *Beauveria* *bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @375 ml / ha recorded 4.67, 5.00 and 5.00 larvae on ten plants, respectively and were superior over untreated control (7.33 larvae on ten plants).

4.1.7.3 Larval population of *H. armigera*, ten days after first spray (Pooled)

Pooled data on larval population of *H. armigera* ten days after first spray tabulated in Table 8 (figure 3) clearly indicated significant superiority of all the treatments over untreated control. Treatments with spinosad @ 0.01 % and endosulfan @ 0.06 %, proved most effective in reducing population up to 1.00 and 1.17 larvae on ten plants, respectively which were at par.

Second group of effective treatments included *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Bacillus thuringiensis* @ 750 ml / ha and *Beauveria bassiana* @ 2.5 kg / ha with 2.33, 2.83, 3.00 and 3.17 larvae on ten plants, respectively recording at par performance. Later treatment was found at par with *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha which recorded 4.17, 4.33 and 4.33 larvae on ten plants, respectively. Treatments *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha (4.67 larvae per ten plants) was less effective but was superior over control (7.50 larvae per ten plants).

4.1.7.4 Larval population of *H. armigera*, fourteen days after first spray (Pooled)

Pooled data regarding larval population of *H. armigera* fourteen days after first spray (Table 8, figure 3) revealed significantly less larval population in all the treatments than control. Minimum population of larvae were recorded in spinosad @ 0.01 % (1.83 larvae per ten plants) and did not differ from endosulfan @ 0.06 % (2.17 larvae per ten plants), which were significantly superior to rest of the treatments.

Treatments, *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE /ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Bacillus thuringiensis* @ 750 ml / ha, fromed next group of better treatments and recorded 3.50, 3.83, 4.17 and 4.17 larvae on ten plants, respectively. Treatments applied in combination viz., *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were less effective and recorded 4.50, 5.00, 5.17, 5.33 and 5.50 larvae on ten plants, respectively, but were superior over control. (7.67 larvae per ten plants).

4.1.7.5 Larval population of *H. armigera*, three days after second spray (Pooled)

Pooled data on larval population of *H. armigera* three days after second spray are presented in Table 9 and illustrated graphically in figure 4. Treatments exhibited significant differences and were superior over untreated control. spinosad

Table 8 : Effect of various treatments on larval population of *H. armigera* at 3, 7, 10 and 14 days after first spray (Pooled)

Treat-ment No.	Treatment	Average larval population of *H. armigera* / ten plants			
		3 days after spraying	7 days after spraying	10 days after spraying	14 days after spraying
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	4.33 (2.06)	4.00 (2.04)	2.83 (1.74)	3.83 (1.95)
T_2	*Beauveria bassiana* (2.5 Kg/ha)	4.67 (2.14)	4.33 (2.12)	3.17 (1.83)	4.17 (2.03)
T_3	*Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	3.67 (1.91)	2.83 (1.75)	2.33 (1.59)	3.50 (1.85)
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	3.83 (1.94)	3.33 (1.88)	3.00 (1.78)	4.17 (2.03)
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	4.67 (2.14)	4.50 (2.17)	4.17 (2.09)	5.00 (2.23)
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	4.83 (2.18)	5.00 (2.28)	4.33 (2.12)	5.33 (2.30)
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	5.00 (2.21)	4.67 (2.20)	4.33 (2.13)	5.17 (2.26)
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	5.00 (2.22)	5.00 (2.28)	4.67 (2.21)	5.50 (2.34)
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	4.33 (2.06)	3.67 (1.96)	3.33 (1.88)	4.50 (2.11)
T_{10}	Endosulfan (0.06 %)	2.00 (1.37)	1.50 (1.28)	1.17 (1.16)	2.17 (1.45)
T_{11}	Spinosad (0.01 %)	1.83 (1.31)	1.17 (1.16)	1.00 (1.07)	1.83 (1.33)
T_{12}	Untreated control	6.83 (2.60)	7.33 (2.75)	7.50 (2.78)	7.67 (2.77)
	'F'test	Sig.	Sig.	Sig.	Sig.
	S.E. (m) ±	0.08	0.08	0.10	0.07
	C.D. at 5%	0.25	0.22	0.30	0.21
	C.V. (%)	10.27	9.38	13.46	8.55

* Figures in parentheses are corresponding square root transformed values

LEGEND

T_1 - *Metarhizium anisopliae* @ 2.5 kg / ha

T_2 - *Beauveria bassiana* @ 2.5 kg / ha

T_3 - HaNPV @ 250 LE / ha

T_4 - Bt @ 750 ml / ha

T_5 - *Metarhizium anisopliae* @ 1.25 kg / ha + HaNPV @125 LE / ha

T_6 - *Metarhizium anisopliae* @ 1.25 kg / ha + Bt @ 375 ml/ha

T_7 - *Beauveria bassiana* @ 1.25 kg / ha + HaNPV @ 250 LE / ha

T_8 - *Beauveria bassiana* @ 1.25 kg / ha + Bt @ 375 ml / ha

T_9 - HaNPV @ 250 LE / ha + Bt @ 375 ml / ha

T_{10} - Endosulfan @ 0.06 %

T_{11} - Spinosad @ 0.01 %

T_{12} - Untreated control

X- axis = Treatments, Y-axis= Larval population per ten plants

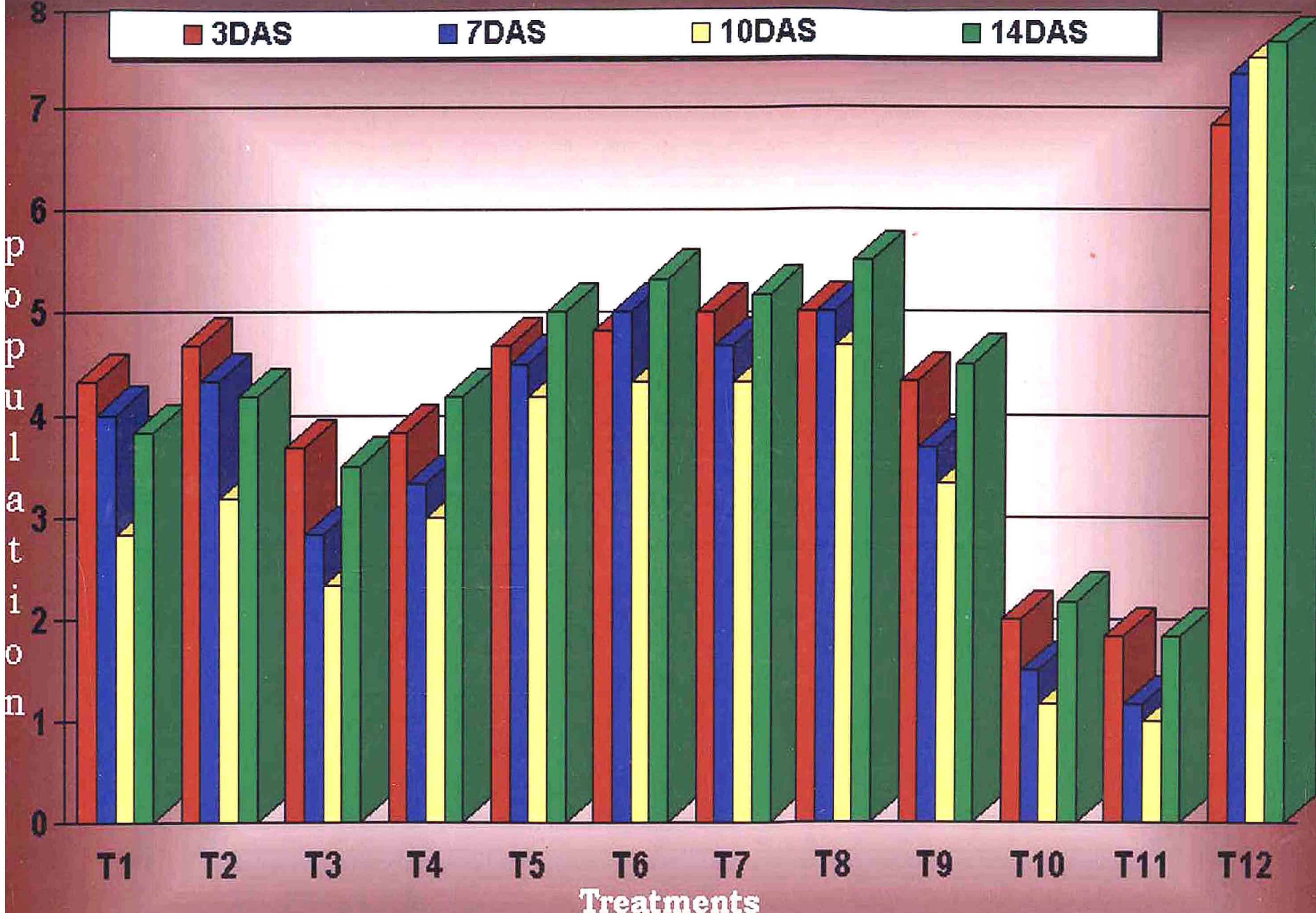

Fig 3. Effect of various treatments on larval population of *H. armigera* at 3, 7, 10 and 14 days after first spray

Cost benefit analysis showed that modules with three sprays of endosulfan was economically most viable recorded highest ICBR followed by module having Bt – HaNPV – endosulfan, endosulfan – Bt – HaNPV and NSKV – Bt – HaNPV. However, modules consisted of Bt – HaNPV – spinosad, Bt – HaNPV – Bt and spinosad – Bt – HaNPV recorded less ICBR.

To study the seasonal incidence of *H. armigera* on chickpea, weekly observations on larval population were taken on ten randomly selected plants from separately sown plot. Results of the study revealed that the highest incidence of pest was favoured by temperature range of 11.9 to 32.2 °C and humidity range of 21 to 64%.

Twenty five eggs and larvae were collected at weekly interval from separately sown field to study the biotic complex of the pest. Eggs kept till hatching while larvae were reared in the laboratory till the adult emergence. The study revealed that only two larval parasitoids viz., *Compoletis chlorideae* and *Eriborous* sp were pre-dominant in chickpea ecosystem parasitized maximum up to 36 % larvae of *H. armigera*.

Effect of malic acid on larval and pupal development was studied by rearing the larvae up to adult stage on malic acid enriched, water washed and untreated chickpea leaves. Observations on larval, pre-pupal and pupal period showed that malic acid has no significant effect on larval and pupal development on *H. armigera*.

@ 0.01 % (0.83 larvae per ten plants) and endosulfan @ 0.06 % (1.17 larvae per ten plants) were most promising and significantly superior over remaining treatments.

A group of next effective treatments in order of merit were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha and *Bacillus thuringiensis* @750 ml / ha which recorded 2.67 and 3.00 larvae per ten plants, respectively. Later treatments was found at par with *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Metarhizium anisopliae* @ 2.5 kg / ha and *Beauveria bassiana* @ 2.5 kg / ha and recorded 3.67, 3.67 and 3.83 larvae on ten plants, respectively. Remaining 4 treatments viz., *Metarhizium anisopliae* @1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha were comparatively less effective and recorded 4.67, 4.83, 5.00 and 5.17 larvae per ten plants, respectively as against 7.33 larvae per ten plants observed in an untreated control.

4.1.7.6 Larval population of *H. armigera*, seven days after second spray (Pooled)

Pooled results for the two years regarding larval population seven days after second spray as influenced by various treatments are presented in table 9 and illustrated graphically in figure 4. All the treatments evaluated exhibited significant differences and recorded significantly lower larval population than control. Treatment spinosad @ 0.01 % and endosulfan @ 0.06 % had statistically at par effects with 0.50 larvae per ten plants. These two treatments were followed by

Helicoverpa armigera nuclear polyhedrosis virus @ 250 LE / ha (1.83 larvae per ten plants) and *Bacillus thuringiensis* @ 750 ml / ha (2.50 larvae per ten plants) which were at par. Third group of better treatments comprised of *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @375 ml / ha, *Metarhizium anisopliae* @ 2.5 kg / ha and *Beauveria bassiana* @2.5 kg / ha exhibited moderate effect and recorded 3.00, 3.17 and 3.50 larvae per ten plants. Remaining four treatments viz., *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 125 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE /ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha exhibited less effect with 4.17, 4.50, 4.67 and 4.83 larvae per ten plants, respectively. Untreated control had registered highest of 7.00 larvae per ten plants.

4.1.7.7 Larval population of *H. armigera*, ten days after second spray (Pooled)

Pooled data regarding larval population of *H. armigera* ten days after second spray as influence by various treatments (Table 9, figure 4) showed significantly lower larval population in all the treatments than control. Amongst various treatments spinosad @ 0.01 % and endosulfan @ 0.06 % recorded least population i.e. 0.33 and 0.50 larvae per ten plants and were at par with each other. Second group of effective treatment were *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Bacillus thuringiensis* @ 750 ml / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha + *Bacillus thuringiensis* @375 ml / ha which recorded 1.50, 1.83, 2.17, 2.17 and 2.50 larvae per ten plants, respectively and were at par and significantly superior over rest of the treatments except the combination of *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha. Other treatments in order of their merit were *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha which recorded 3.50, 3.83, 3.83 and 4.17 larvae on ten plants, respectively. Untreated plots has registered highest population of larvae i.e. 6.50 per ten plants.

4.1.7.8 Larval population of *H. armigera*, fourteen days after second spray (Pooled)

Pooled data on population of *H. armigera* fourteen days after second spray (Table 9, figure 4) pertaining to various treatments were significant. All the treatments showed significant effect in reducing larval population than control. spinosad @ 0.01 % was most effective (0.17 larvae per ten plants) than other treatments except endosulfan @ 0.06 % (0.67 larvae per ten plants). Both these treatments were followed by *Helicoverpa armigera* nuclear polyhedrosis virus @250 LE / ha, *Metarhizium anisopliae* @2.5 kg / ha, *Beauveria bassiana* @ 2.5 kg / ha and *Bacillus thuringiensis* @ 750 ml / ha which recorded 1.67, 1.83, 2.33 and 2.50 larvae on ten plants, respectively. However, later three treatments were found at par with combination of *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha with *Bacillus thuringiensis* @375 ml / ha (2.67 larvae per ten plants). Other treatments, *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha,

Table 9 : Effect of various treatments on larval population of *H. armigera* at 3, 7, 10 and 14 days after second spray (Pooled)

Treat-ment No.	Treatment	Average larval population of *H. armigera* / ten plants			
		3 days after spraying	7 days after spraying	10 days after spraying	14 days after spraying
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	3.67 (1.97)	3.17 (1.91)	1.83 (1.51)	1.83 (1.51)
T_2	*Beauveria bassiana* (2.5 Kg/ha)	3.83 (2.02)	3.50 (1.99)	2.17 (1.63)	2.33 (1.68)
T_3	*Helicòverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	2.67 (1.70).	1.83 (1.52)	1.50 (1.40)	1.67 (1.45)
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	3.00 (1.78)	2.50 (1.73)	2.17 (1.62)	2.50 (1.72)
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	4.67 (2.21)	4.17 (2.15)	3.50 (1.99)	3.33 (1.94)
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	5.00 (2.29)	4.67 (2.27)	3.83 (2.07)	3.83 (2.08)
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	4.83 (2.25)	4.50 (2.23)	3.83 (2.08)	3.50 (1.99)
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	5.17 (2.32)	4.83 (2.30)	4.17 (2.15)	4.00 (2.12)
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	3.67 (1.97).	3.00 (1.86)	2.50 (1.72)	2.67 (1.77)
T_{10}	Endosulfan (0.06 %)	1.17 (1.15)	0.50 (0.97)	0.50 (0.97)	0.67 (1.03)
T_{11}	Spinosad (0.01 %)	0.83 (1.03)	0.50 (0.97)	0.33 (0.88)	0.17 (0.79)
T_{12}	Untreated control	7.33 (2.75)	7.00 (2.73)	6.50 (2.64)	6.33 (2.61)
	'F'test	Sig.	Sig.	Sig.	Sig.
	S.E. (m) $\pm$	0.08	0.07	0.11	0.10
	C.D. at 5%	0.24	0.22	0.33	0.29
	C.V. (%)	10.41	9.55	15.93	14.22

* Figures in parentheses are corresponding square root transformed values

LEGEND

T_1 - *Metarhizium anisopliae* @ 2.5 kg / ha

T_2 - *Beauveria bassiana* @ 2.5 kg / ha

T_3 - HaNPV @ 250 LE / ha

T_4 - Bt @ 750 ml / ha

T_5 - *Metarhizium anisopliae* @ 1.25 kg / ha + HaNPV @125 LE / ha

T_6 - *Metarhizium anisopliae* @ 1.25 kg / ha + Bt @ 375 ml/ha

T_7 - *Beauveria bassiana* @ 1.25 kg / ha + HaNPV @ 250 LE / ha

T_8 - *Beauveria bassiana* @ 1.25 kg / ha + Bt @ 375 ml / ha

T_9 - HaNPV @ 250 LE / ha + Bt @ 375 ml / ha

T_{10} - Endosulfan @ 0.06 %

T_{11} - Spinosad @ 0.01 %

T_{12} - Untreated control

X- axis = Treatments, Y-axis= Larval population per ten plants

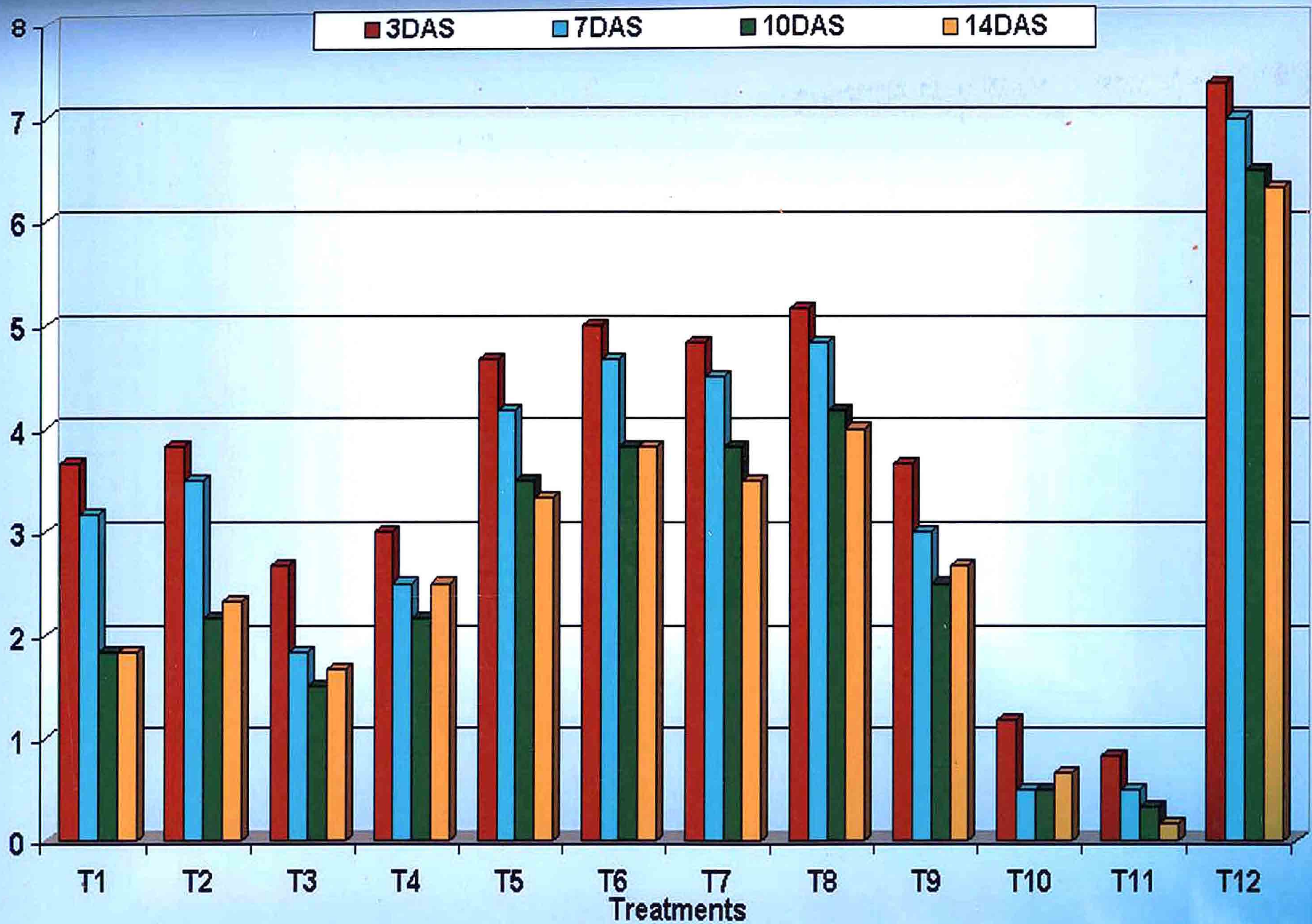

Fig 4. Effect of various treatments on larval population of *H. armigera* at 3, 7, 10 and 14 days after second spray

Metarhizium anisopliae @1.25 kg / ha + *Bacillus thuringiensis* @375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha had recorded 3.33, 3.50, 3.83 and 4.00 larvae on ten plants, respectively. Highest number of Helicoverpa larvae were recorded in untreated plants (6.33 per ten plants).

4.1.8 Effect of various treatments on grain yield of chickpea (Pooled)

Pooled data on grain yield as influenced by various treatments are presented in Table 10 and illustrated graphically in figure 5. All the treatments evaluated were significantly superior over control and produced higher yield than the control. Maximum grain yield was registered in spinosad @ 0.01 % (15.59 q / ha) followed by endosulfan @ 0.06 % (15.15 q / ha) than rest of the treatments.

Next effective group of treatments yielding higher grain yield were Helicoverpa armigera nuclear polyhedrosis virus @ 250 LE / ha (13.73 q / ha), *Bacillus thuringiensis* @ 750 ml / ha (13.48 q / ha) and *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha (13.29 q / ha). Later treatment was also found at par with *Metarhizium anisopliae* @2.5 kg / ha (12.99 q / ha) and *Beauveria bassiana* @2.5 kg / ha (12.74 q / ha).

Treatment *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @375 ml / ha recorded comparatively lower grain yield (10.63 q / ha) and was at par with *Metarhizium anisopliae* @1.25 kg / ha + *Bacillus thuringiensis* @375ml / ha (11.08 q / ha), *Beauveria bassiana* @1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE / ha (11.28 q / ha) and *Metarhizium anisopliae* @1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @125 LE / ha (11.64 q / ha) which were significantly inferior to rest of the treatments, while minimum yield of 9.66 q / ha was obtained from untreated plots.

Table 10 : Effect of various treatments on grain yield of chickpea and incremental cost benefit ratio (pooled)

Treatment No.	Treatment	Mean yield (q / ha)	ICBR	Rank
T_1	*Metarhizium anisopliae* (2.5 Kg/ha)	12.99	1 : 1.39	7
T_2	*Beauveria bassiana* (2.5 Kg/ha)	12.74	1 : 1.47	6
T_3	*Helicoverpa armigera* nuclear polyhedrosis virus (250 LE/ha)	13.73	1 : 3.67	2
T_4	*Bacillus thuringiensis* (PDKV) (750 ml /ha)	13.48	1 : 2.93	4
T_5	*Metarhizium anisopliae* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	11.64	1 : 1.13	8
T_6	*Metarhizium anisopliae* (1.25 kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	11.08	1 : 0.77	10
T_7	*Beauveria bassiana* (1.25 Kg/ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha)	11.28	1 : 1.01	9
T_8	*Beauveria bassiana* (1.25 Kg/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	10.63	1 : 0.57	11
T_9	*Helicoverpa armigera* nuclear polyhedrosis virus (125 LE/ha) + *Bacillus thuringiensis* (PDKV) (375 ml/ha)	13.29	1 : 3.01	3
T_{10}	Endosulfan (0.06 %)	15.15	1 : 6.87	1
T_{11}	Spinosad (0.01 %)	15.59	1 : 2.50	5
T_{12}	Untreated control	9.66	--	--
	'F'test	Sig.		
	S.E. (m) ±	0.33		
	C.D. at 5%	0.97		
	C.V. (%)	4.81		

LEGEND

T_1 - *Metarhizium anisopliae* @ 2.5 kg / ha

T_2 - *Beauveria bassiana* @ 2.5 kg / ha

T_3 - HaNPV @ 250 LE / ha

T_4 - Bt @ 750 ml / ha

T_5 - *Metarhizium anisopliae* @ 1.25 kg / ha + HaNPV @125 LE / ha

T_6 - *Metarhizium anisopliae* @ 1.25 kg / ha + Bt @ 375 ml/ha

T_7 - *Beauveria bassiana* @ 1.25 kg / ha + HaNPV @ 250 LE / ha

T_8 - *Beauveria bassiana* @ 1.25 kg / ha + Bt @ 375 ml / ha

T_9 - HaNPV @ 250 LE / ha + Bt @ 375 ml / ha

T_{10} - Endosulfan @ 0.06 %

T_{11} - Spinosad @ 0.01 %

T_{12} - Untreated control

X- axis = Treatments, Y-axis= Grain yield (q / ha)

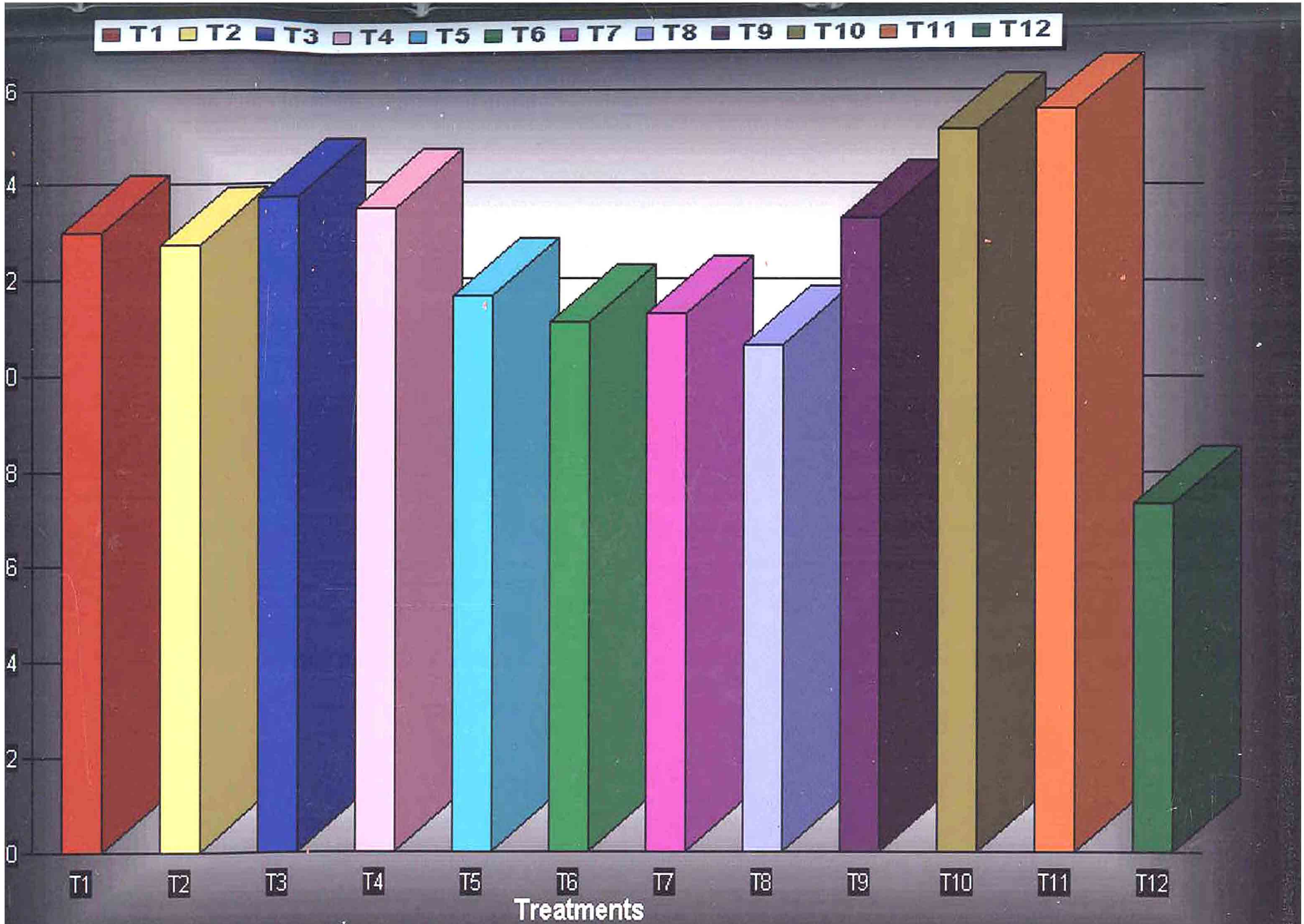

Fig 5. Effect of various treatments on grain yield of chickpea

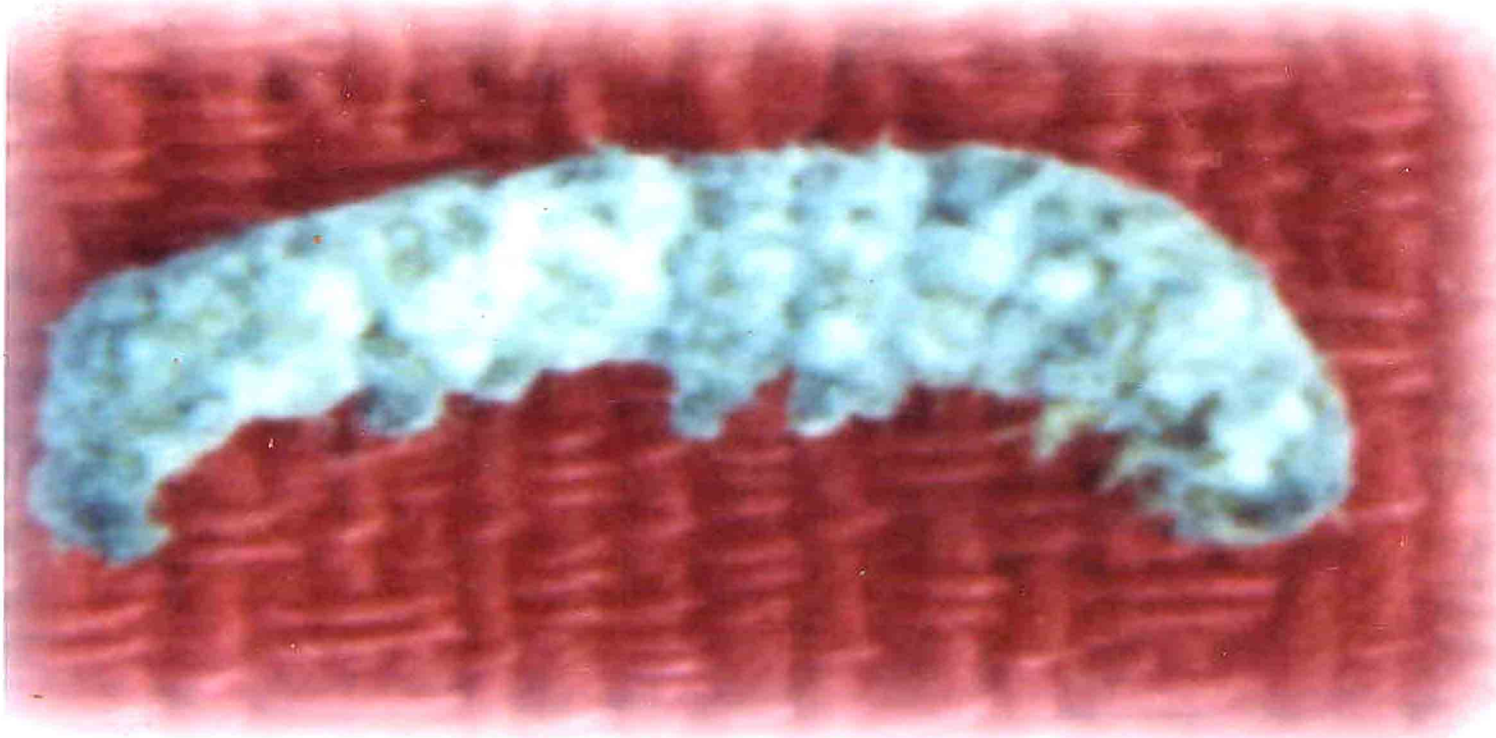

Plate 1. Mummified *H. armigera* larva due to *Metarhizium anisopliae*

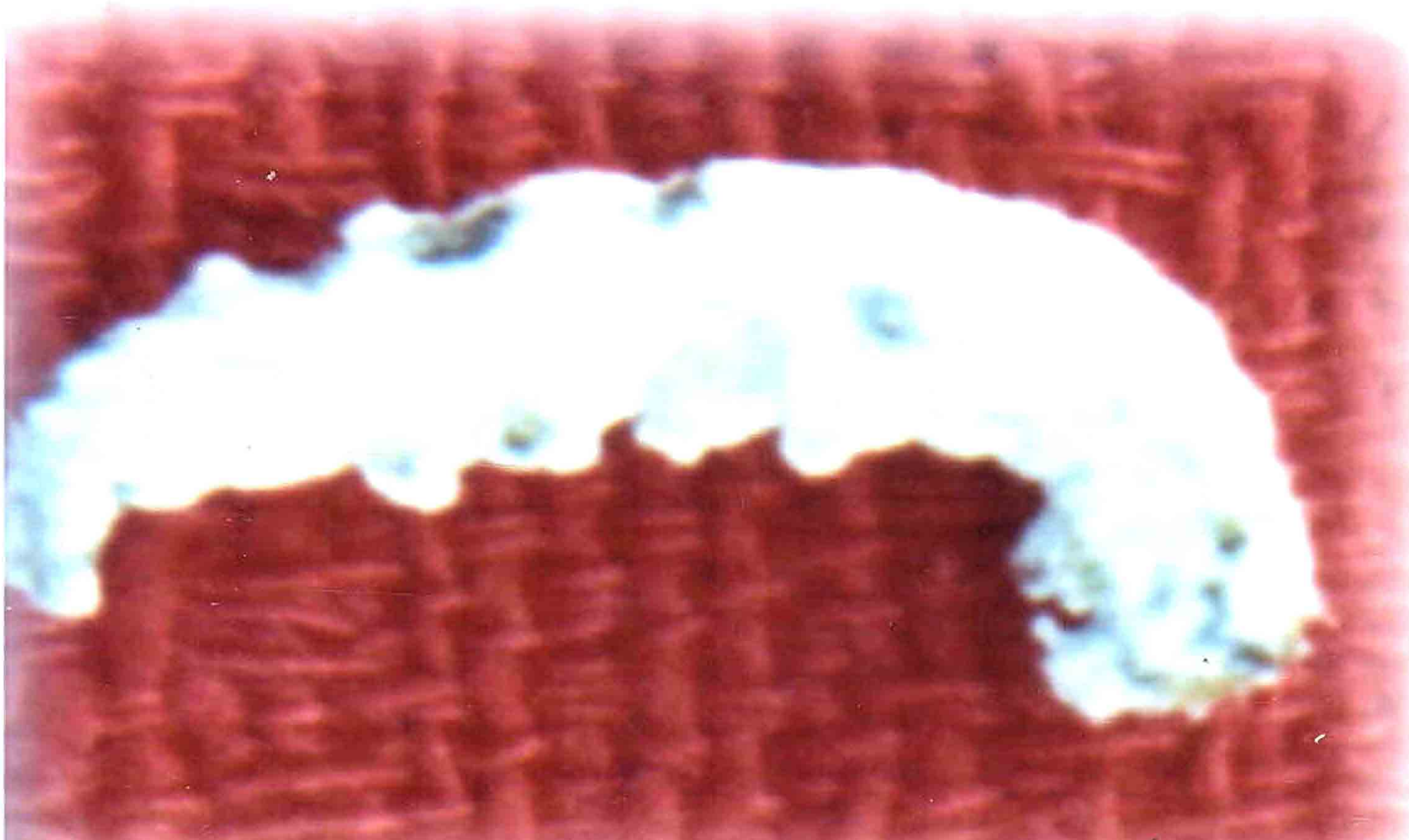

Plate 2. Mummified *H. armigera* larva

Plate 3. *H armigera* larva infected by *HaNPV*

Plate 4. *H. armigera* larva infected by *Bacillus thuringiensis*

Plate 5. Dead *H. armigera* larva due to spinosad treatment

Plate 6. Dead *H. armigera* larva due

4.1.9 Incremental cost benefit ratio of various treatments (Pooled)

The data on the impact of various treatments on the economical returns over two seasons presented in Table 10 (Appendix - D) confirmed that application of endosulfan @ 0.06 % was economically most viable treatment and gave maximum ICBR of 1 : 6.87. The next effective treatments in order were, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thringiensis* @ 375 ml / ha, *Bacillus thringiensis* @ 750 ml / ha and spinosad @ 0.01 % with ICBR of 1 : 3.67, 1 : 3.01, 1 : 2.93, 1 : 2.50, respectively.

The treatments, *Beauveria bassiana* @ 2.5 kg / ha, *Metarhizium anisopliae* @ 2.5 kg / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thringiensis* @ 375 ml / ha were less economical and exhibited ICBR of 1 : 1.47, 1 : 1.39, 1 : 1.13, 1 : 1.01, 1 : 0.77 and 1 : 0.57, respectively.

4.2 Evaluation of different bio-intensive modules for management of *H. armigera*

4.2.1 Effect of various modules on larval population of *H. armigera* during 2003-04

Data on cumulative average larval population of *H. armigera* in different modules are presented in table 11. All the modules tested were effective in reducing the larval population than untreated control. However, amongst the different modules tested module M_7 consisted of three sprays of endosulfan @0.06% and module M_5 consisted of *Bacillus thuringiensis* @ 750 ml / ha –

Table 11 : Effect of various modules on larval population of *H. armigera* during 2003-04

Module No.	Components of Module	Cumulative average population of *H. armigera* / ten plants
M_1	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha.	2.67 (1.63)
M_2	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %	1.89 (1.37)
M_3	Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	2.25 (1.50)
M_4	Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	2.83 (1.68)
M_5	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad 0.01 %.	1.56 (1.24)
M_6	Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	2.03 (1.42)
M_7	Three sprays of Endosulfan @ 0.06 %.	1.42 (1.19)
M_0	Untreated Control	5.78 (2.40)
	'F'test	Sig.
	S.E. (m) ±	0.05
	C.D. at 5%	0.17
	C.V. (%)	5.92

* Average of 12 observations taken at 3, 7, 10 and 14 days after each spray

** Figures in the parentheses are corresponding square root transformed values

Helicoverpa armigera nuclear polyhedrosis virus @ 250 LE / ha - spinosad @ 0.01 % were most effective, statistically at par and recorded 1.42 and 1.56 larvae per ten plants, respectively.

Modules M_2 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - endosulfan @ 0.06 %), M_6 (spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) and M_3 (endosulfan @0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) were moderately effective, statistically at par and recorded 1.89, 2.03 and 2.25 larvae per ten plants, respectively. Module M_1 consisted of *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha and module M_4 consisted of Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha were least effective, statistically at par and recorded 2.67 and 2.83 larvae per ten plants, respectively. An untreated control had registered the average larval population of 5.78 per ten plants.

4.2.2 Effect of various modules on grain yield of chickpea during 2003-04

Data on the grain yield of chickpea has influenced by various modules are presented in Table 12. All the modules evaluated produced significantly higher grain yield than untreated control. However, module M_7 (Three sprays of Endosulfan @ 0.06 %), M_5 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad 0.01 %) and M_2 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %) produced significantly higher grain yield i.e. 16.70, 16.43 and 16.21 q / ha, respectively and were at par with each other.

Module M_6 comprising spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, M_3 consisting of endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha and M_1 having *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha were statistically at par, moderately effective and produced 15.77, 15.57 and 15.23 q / ha grain yield, respectively.

Module M_4 consisting Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha was least effective and recorded 14.87 q / ha grain yield but was significantly superior over untreated control which recorded 10.45 q / ha grain yield.

4.2.3 Incremental cost benefit ratio of various modules during 2003-04

Incremental Cost Benefit Ratio of various modules presented in Table 12 (Appendix – E) showed that, maximum return of Rs.5.47 per rupee invested was obtained from the module 7 consisted of three sprays of endosulfan@ 0.06 %. This module was followed by module M_2 (*Bacillus thringiensis* @ 750 ml / ha – *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha – endosulfan @ 0.06 %), M3 (Endosulfan @ 0.06 % - *Bacillus thringiensis* @750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @250 LE / ha), M4 (Neem Seed

Table 12 : Effect of various modules on grain yield of chickpea and incremental cost benefit ratio during 2003-04

Module No	Components of Module	Mean yield (q / ha)	ICBR	Rank
M_1	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha.	15.23	1 : 2.30	6
M_2	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %	16.21	1 : 3.42	2
M_3	Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	15.57	1 : 3.04	3
M_4	Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	14.87	1 : 2.82	4
M_5	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad 0.01 %.	16.43	1 : 2.46	5
M_6	Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	15.77	1 : 2.19	7
M_7	Three sprays of Endosulfan @ 0.06 %.	16.70	1 : 5.47	1
M_0	Untreated Control	10.45	--	--
	'F'test	Sig.		
	S.E. (m) ±	0.19		
	C.D. at 5%	0.62		
	C.V. (%)	2.18		

kernel entract @ 5 % - *Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) and M5 (*Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha –' spinosad@ 0.01 %) which gave return of Rs.3.42, 3.04, 2.82 and 2.46, respectively.

The modules M1 (*Bacillus thringiensis* @ 250 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thringiensis* @ 750 ml / ha) and M6 (spinosad @ 0.01 % - *Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) gave comparatively less return per rupee invested i.e. Rs.2.30 and 2.19, respectively.

4.2.4 Effect of various modules on larval population of *H. armigera* during 2004-05

Cumulative average larval population of *H. armigera* in different modules are presented in Table 13. It revealed superiority of all the modules in reducing larval population of *H. armigera* over untreated control. However, module M_7 comprising three sprays of endosulfan @ 0.06 % and module M_5 containing *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - spinosad 0.01 % proved most effective and were at par with each other. They have recorded 3.22 and 3.58 larvae per ten plants, respectively.

Module M_5 however did not differ significantly from M_2 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - endosulfan @ 0.06 %) and M_6 (spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) which recorded 3.92 and 4.11 larvae per ten plants, respectively.

Table 13 : Effect of various modules on larval population of *H. armigera* during 2004-05

Module No.	Components of Module	Cumulative average population of *H. armigera* / ten plants
M_1	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha.	5.08 (2.25)
M_2	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %	3.92 (1.98)
M_3	Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	4.31 (2.07)
M_4	Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	5.47 (2.34)
M_5	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad 0.01 %.	3.58 (1.89)
M_6	Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	4.11 (2.03)
M_7	Three sprays of Endosulfan @ 0.06 %.	3.22 (1.80)
M_0	Untreated Control	8.39 (2.90)
	'F'test	Sig.
	S.E. (m) ±	0.04
	C.D. at 5%	0.14
	C.V. (%)	3.33

* Average of 12 observations taken at 3, 7, 10 and 14 days after each spray

** Figures in the parentheses are corresponding square root transformed values

These two modules (M_2 and M_6) were also at par with M_3 (endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) which recorded 4.31 larvae per ten plants.

Module M_1 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha) M_4 (Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) were comparatively less effective, statistically at par and recorded 5.08 and 5.47 larvae on ten plants, respectively. An untreated control had registered the maximum larval population of 8.39 larvae per ten plants.

4.2.5 Effects of various modules on grain yield of chickpea during 2004-05

Data on grain yield of chickpea as influenced by various modules are presented in Table 14. Amongst different modules evaluated, module M_7 composing three sprays of endosulfan @ 0.06 % recorded highest grain yield 15.21 q / ha and was at par with M_5 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - spinosad @ 0.01 % and M_2 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - endosulfan @ 0.06 %) which recorded 14.82 and 14.72 q / ha grain yield, respectively.

Module M_6 comprising spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha and M_3 consisting endosulfan @ 0.06 %- *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha were moderately effective, statistically equal in effects and recorded 14.29 and 14.11 q / ha grain

Table 14 : Effect of various modules on grain yield of chickpea and incremental cost benefit ratio during 2004-05

Module No	Components of Module	Mean yield (q / ha)	ICBR	Rank
M_1	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha.	13.53	1 : 2.85	7
M_2	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %	14.72	1 : 2.92	2
M_3	Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	14.11	1 : 2.59	3
M_4	Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	13.13	1 : 2.22	4
M_5	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad 0.01 %.	14.82	1 : 2.05	5
M_6	Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	14.29	1 : 1.86	6
M_7	Three sprays of Endosulfan @ 0.06 %.	15.21	1 : 4.69	1
M_0	Untreated Control	09.30	--	--
	'F'test	Sig.		
	S.E. (m) ±	0.17		
	C.D. at 5%	0.57		
	C.V. (%)	2.21		

yield. Module M_1 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha) and M_4 (Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) were less effective at par and recorded 13.53 and 13.13 q / ha grain yield, respectively. Untreated control (M_0) registered significantly minimum yield of 9.30 q / ha.

4.2.6 Incremental cost benefit ratio of various treatments during 2004 –05

Data presented in Table 14 (Appendix - F) showed that module with three sprays of endosulfan 0.06 % emerged as most economical module which gave maximum return of Rs.4.69 per rupee invested. The next economical module in order were M_2 (*Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha- endosulfan @ 0.06 %), M_3 (Endosulfan @ 0.06 %- *Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha), M_4 (Neem seed kernel entract @ 5% - *Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha), M_5 (*Bacillus thringiensis* @ 750 LE / ha- *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha – spinosad @ 0.01 %) and M_6 (Spinosad @ 0.01 % - *Bacillus thringiensis* @ 750 LE / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) which give return of rupees Rs.2.29, 2.59, 2.22, 2.05 and 1.86, respectively per rupee investe.

However, module M_1 consisted of *Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thringiensis* @ 750 ml / ha was comparatively less economical and gave Rs. 1.85 against the investment of one rupee.

4.2.7 Effects of various modules on larval population of *H. armigera* (Pooled)

Data on cumulative average larval population of *H. armigera* in different modules are presented in Table 15 (figure 6). All the modules evaluated, recorded significantly lower larval population than untreated control. However, module M_7 (three sprays of endosulfan @ 0.06 %) and M_5 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha – spinosad @ 0.01 %) proved most effective and recorded minimum larval population of 2.32 and 2.57 per ten plants, respectively and were at par with each other.

Module M_2 comprising *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - endosulfan @ 0.06 %, M_6 consisting spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha and M_3 with spray of endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha were at par with each other and recorded 2.90, 3.07 and 3.28 larvae per ten plants, respectively.

Module M_1 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha) and M_4 (Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) were less effective, statistically at par and recorded 3.88 and 4.15 larvae on ten plants, respectively. An untreated control (M_0) had registered highest of 7.08 larvae per ten plants.

Table 15 : **Effect of various modules on larval population of *H. armigera* (Pooled)**

Module No.	Components of Module	Cumulative average population of *H. armigera* / ten plants
M_1	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha.	3.88 (1.94)
M_2	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %	2.90 (1.68)
M_3	Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	3.28 (1.79)
M_4	Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	4.15 (2.01)
M_5	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad 0.01 %.	2.57 (1.57)
M_6	Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	3.07 (1.72)
M_7	Three sprays of Endosulfan @ 0.06 %.	2.32 (1.49)
M_0	Untreated Control	7.08 (2.65)
	'F'test	Sig.
	S.E. (m) ±	0.04
	C.D. at 5%	0.11
	C.V. (%)	4.87

* Average of 12 observations taken at 3, 7, 10 and 14 days after each spray

** Figures in the parentheses are corresponding square root transformed values

LEGEND:

M_1 -	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha
M_2 -	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %
M_3 -	Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha
M_4 -	Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha
M_5 -	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad @ 0.01 %
M_6 -	Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha
M_7 -	Endosulfan @ 0.06 % (3 sprays)
M_0 -	Untreated control

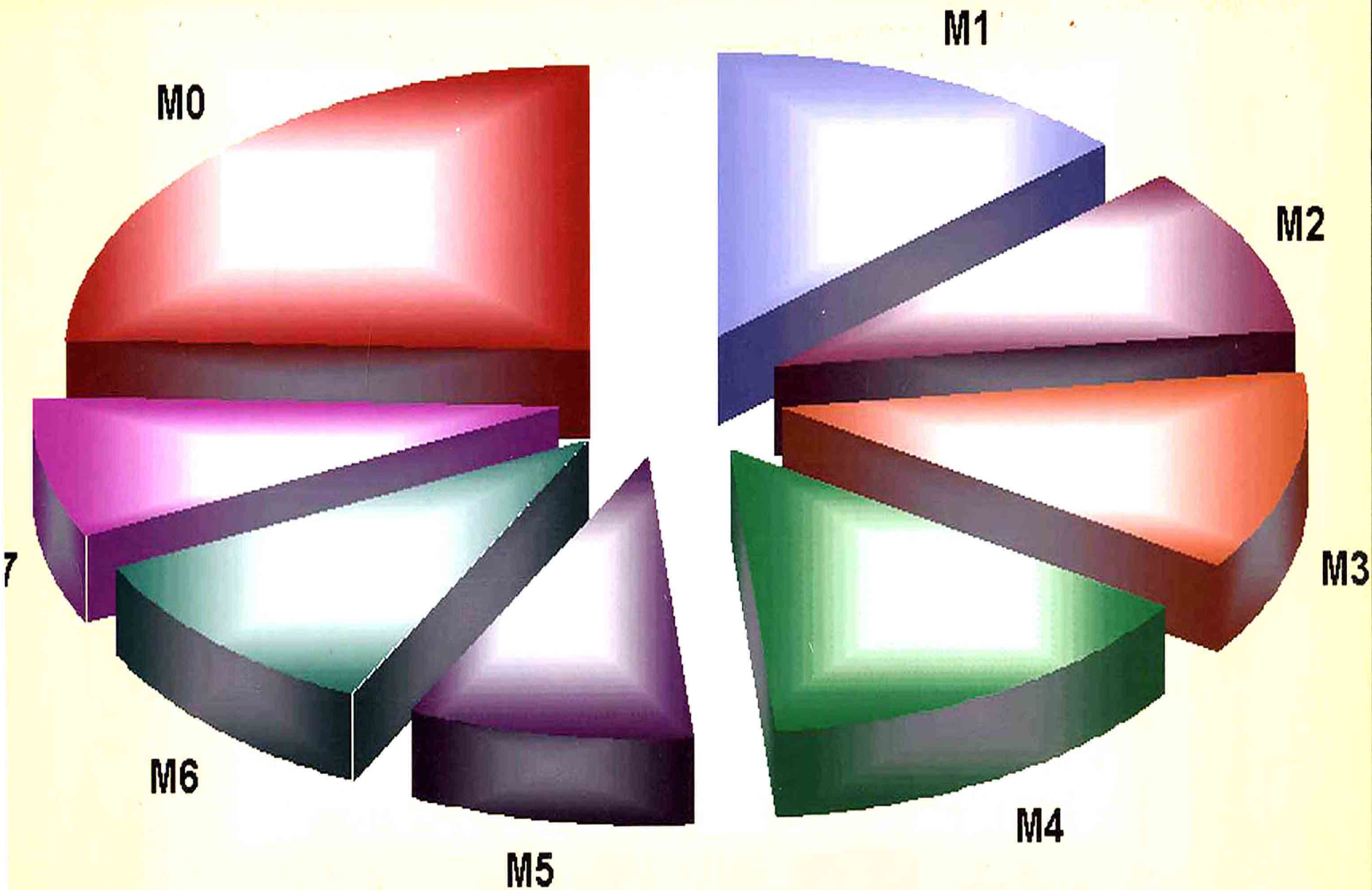

Fig 6. Effect of various modules on larval population of *H. armigera*

4.2.8 Effects of various modules on grain yield of chickpea (Pooled)

The data regarding grain yield of chickpea as influenced by different modules are presented in Table 16 (figure 7). It revealed significant superiority of all the modules over control. Module M_7 with three sprays of endosulfan @ 0.06 % and M_5 consisting *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - spinosad @ 0.01 % were most effective, statistically same and produced 15.96 and 15.63 q / ha grain yield. Module M_5 was also found at par with M_2 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - endosulfan @ 0.06 %) which produced 15.47 q / ha grain yield.

Other effective modules were M_6 (spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) and M_3 (endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) which did not differ significantly and recorded 15.03 and 14.84 q / ha grain yield. Module M_1 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha) and M_4 (Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) were less effective but recorded significantly higher grain yield (14.38 and 14.00 q / ha.) than untreated control (M_0) (9.88 q / ha).

4.2.9 Incremental cost benefit ratio of various modules (Pooled)

Incremental cost benefit ratio of various modules over two seasons presented in Table 16 (Appendix-6) confirmed the economic viability of module 7 consisted of three sprays of endosulfan @ 0.06 % as this module gave highest

Table 16: Effect of various modules on grain yield of chickpea and incremental cost benefit ratio (Pooled)

Module No.	Components of Module	Mean yield (q / ha)	ICBR	Rank
M_1	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha.	14.38	1 : 2.07	6
M_2	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %	15.47	1 : 3.16	2
M_3	Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	14.84	1 : 2.81	3
M_4	Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	14.00	1 : 2.51	4
M_5	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad 0.01 %.	15.63	1 : 2.25	5
M_6	Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha	15.03	1 : 2.02	7
M_7	Three sprays of Endosulfan @ 0.06 %.	15.96	1 : 5.07	1
M_0	Untreated Control	09.88	--	--
	'F'test	Sig.		
	S.E. (m) ±	0.12		
	C.D. at 5%	0.37		
	C.V. (%)	2.10		

LEGEND

M_1	-	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha
M_2	-	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Endosulfan @ 0.06 %
M_3	-	Endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha
M_4	-	Neem Seed Kernel Extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha
M_5	-	*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - Spinosad @ 0.01 %
M_6	-	Spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha
M_7	-	Endosulfan @ 0.06 % (3 sprays)
M_0	-	Untreated control

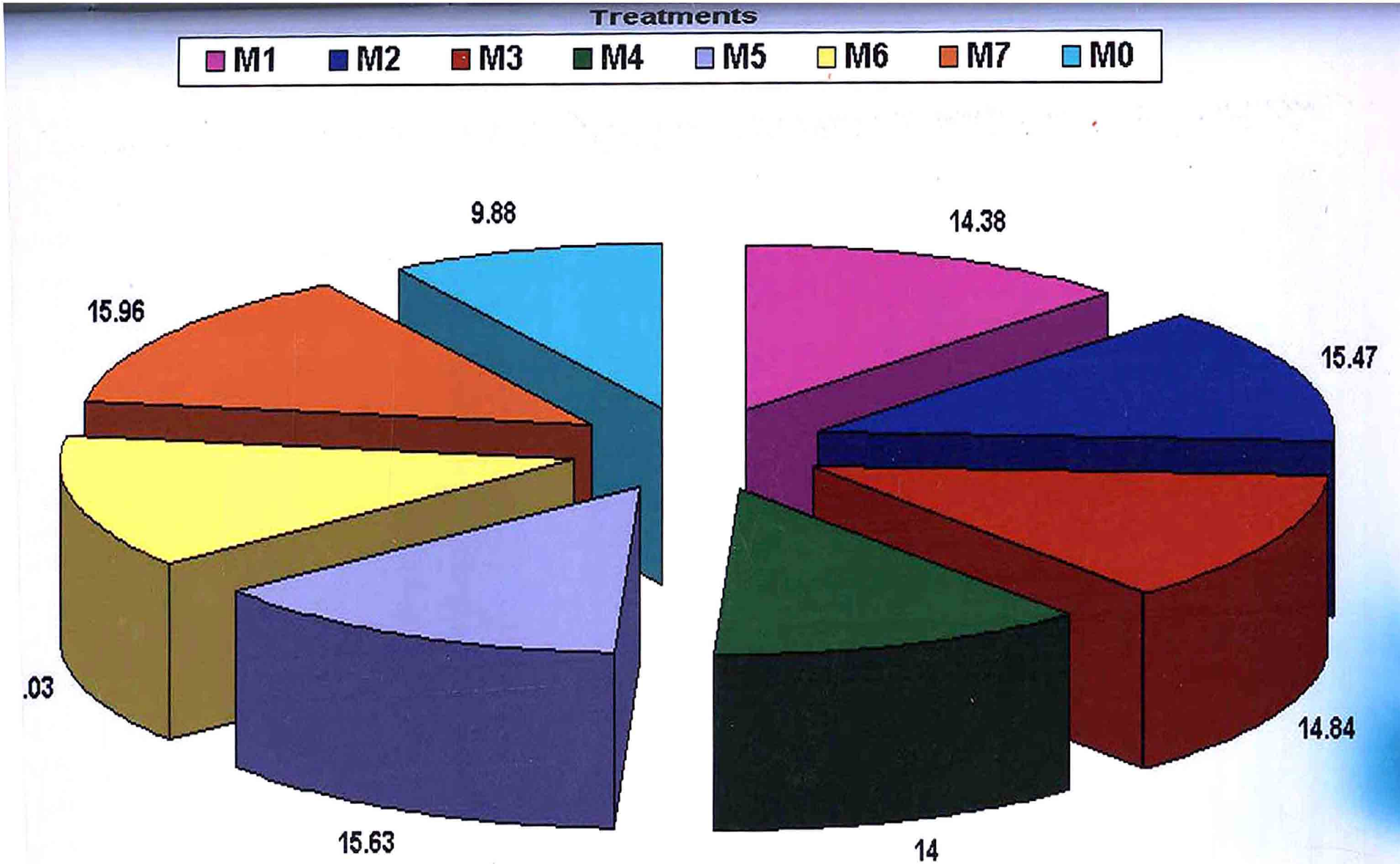

Fig 7. Effect of various modules on grain yield of chickpea

return of Rs.5.07 against a rupee invested. The module M_2 (*Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha- endosulfan @ 0.06 %), M_3 (endosulfan @ 0.06 %- *Bacillus thringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) and M_4 (Neem seed kernel extract @ 5% - *Bacillus thringiensis* @ 750 ml / ha – *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha stand next to module M_7 and gave a return of Rs.3.16, 2.81 and 2.51, respectively per rupee invested.

Remaining modules viz., M_5 (*Bacillus thringiensis* @ 750 LE / ha- *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha – spinosad @ 0.01 %), M1 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha) and M6 (spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus) were proved less economical and gave a return of Rs.2.25, 2.07 and 2.02, respectively for a rupee invested.

4.3 Relationship between larval population of *H. armigera* its field parasitization and weather parameters

Weekly data on population of *H. armigera,* it's parasitization under field conditions and the meteorological parameters obtained during *rabi*, 2003-04 and 2004-05 are presented in Table 17 and 18 and illustrated graphically in figure 8 and 9. Co-relation coefficients obtained between above variables are given in Table 19.

4.3.1 Seasonal incidence of *H. armigera*

It is seen from the Table 17 and figure 8 that, the incidence of *H. armigera* during *rabi*, 2003-04 was initiated during 45th meteorological week (3 larvae / 10 plants) i.e. nearly one month after sowing. It went on increasing and reached its

Table 17 : Weekly larval population of *H. armigera*, field parasitization and weather parameters during 2003-04

Met. Week	Period	Larval population / 10 plants	Per cent parasitization due to			Meteorological Parameters				
						Temperature (°C)		Relative Humidity (%)		Rainfall (mm)
			C. chlorideae	*Eriborus* sp	Both parasitoids	Max.	Min.	Mor.	Even	
45	05-11 Nov., 2003	3	4	0	4	32.3	20.2	85	57	0.5
46	12-18 Nov., 2003	4	0	4	4	33.0	16.0	65	32	0
47	19-25 Nov., 2003	5	4	0	4	31.6	14.6	70	34	0
48	26-02 Dec., 2003	5	4	8	12	32.3	15.7	71	29	0
49	03-09 Dec., 2003	7	12	0	12	32.2	16.5	77	33	0
50	10-16 Dec., 2003	7	20	4	24	31.2	11.9	64	21	0
51	17-23 Dec., 2003	6	16	12	28	31.4	12.6	63	26	0
52	24-31 Dec., 2003	4	8	4	12	28.6	10.8	72	30	0
1	01-07 Jan., 2004	3	16	0	16	26.8	10.3	72	36	4.9
2	08-14 Jan., 2004	0	0	0	0	28.1	12.6	75	39	3.8

NB : Larval population and per cent parasitization is of corresponding week, while weather parameters are of previous week
No egg and Pupal parasitoids were recorded.

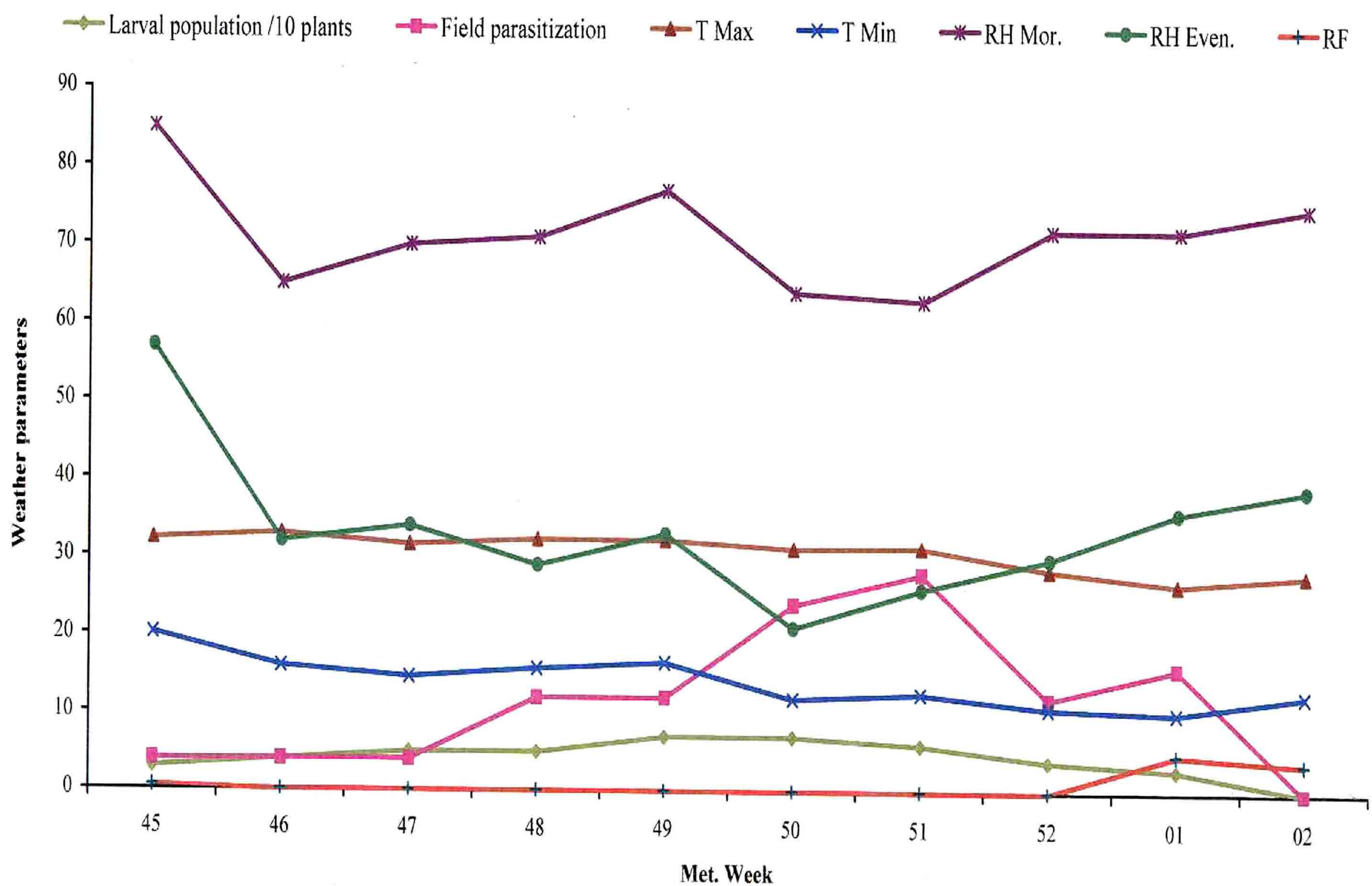

Fig. 8. Weekly larval population of *H. armigera*, field parsitization and weather parameters during 2003-04

Table 18 : Weekly larval population of *H. armigera* , field parasitization and weather parameters during 2004-05.

Met. Week	Period	Larval population / 10 plants	Per cent parasitization due to			Meteorological Parameters				
						Temperature (°C)		Relative Humidity (%)		Rainfall (mm)
			C. chlorideae	*Eriborus* sp	Both parasitoids	Max.	Min.	Mor.	Even	
44	29-04 Nov., 2004	3	4	0	4	33.0	14.6	64	19	0
45	05-11 Nov., 2004	5	0	8	8	32.2	15.2	65	27	0
46	12-18 Nov., 2004	5	8	4	12	31.7	16.3	72	38	0
47	19-25 Nov., 2004	9	12	0	12	31.8	18.3	86	41	41
48	26-02 Dec., 2004	13	24	12	36	32.0	12.9	66	22	0
49	03-09 Dec., 2004	8	12	4	16	30.5	11.7	67	23	0
50	10-16 Dec., 2004	9	18	8	24	29.8	10.2	62	23	0
51	17-23 Dec., 2004	7	16	4	20	30.1	10.3	68	22	0
52	24-31 Dec., 2004	6	8	0	8	30.4	9.8	66	23	0
1	01-07 Jan., 2005	4	0	0	0	29.8	11.9	69	32	0
2	08-14 Jan., 2005	3	0	4	4	30.6	15.1	75	37	0

NB : Larval population and per cent parasitization is of corresponding week, while weather parameters are of previous week
No egg and pupal parasitoids were recorded

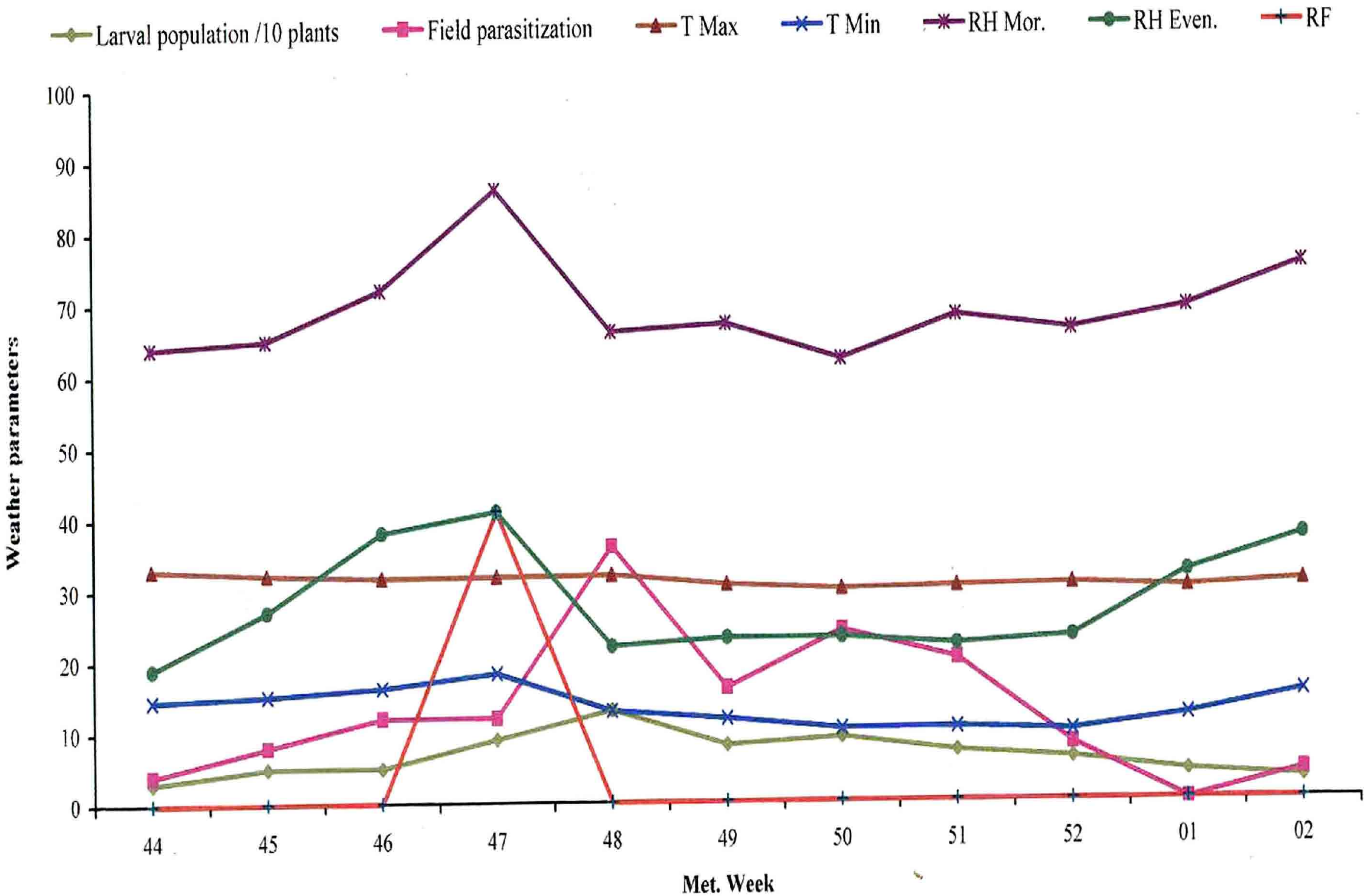

Fig. 9. Weekly larval population of *H. armigera* , field parsitization and weather parameters during 2004-05

peak (7 larvae / 10 plants) during 49th and 50th meteorological week with a temperature variation of 16.5 to 32.2 °C and 11.9 to 31.2 °C while relative humidity between 33 to 77 % and 21 to 64 %, respectively during it's previous week. Further it declined up to 1st meteorological week and was zero during 2nd meteorological week.

During *rabi*, 2004-05 the incidence of *H. armigera* was noticed during 44th meteorological week (Table 18, figure 9) i.e. 3 larvae / 10 plants with temperature between 14.6 to 33.0 °C, relative humidity 29 to 64 % and no rainfall during its previous week. Highest population of pests (13 larvae / 10 plants) was recorded in 48th meteorological week with temperature between 12.2 to 32.0 °C, relative humidity 22 to 66 %, no rainfall during its previous week. Afterwards the population started decreasing and was minimum (3 larvae / 10 plants) during 2nd meteorological week

4.3.2 Parasitization of the pest

During both the years of investigation no egg and pupal parasitoids recorded. Only two larval parasitoids viz., *Campoletis chlorideae* and *Eriborus* sp (Plate 7 and 8) were found parasitizing *H. armigera* larvae. The data on parasitization due to these two parasitoids during *rabi*, 2003-04 and 2004-05 are presented in Table 17 and 18 and illustrated graphically in figure 8 and 9.

During 2003-04, the highest parasitization due to *Compoletis chlorideae* (20 %) was recorded in 50th meteorological week where as the parasitization due to *Eriborus sp* was highest (12 %) in 51st meteorological week. The total parasitization due to both parasitoids was highest during 51st meteorological week i.e. 28 per cent. The temperature and relative humidity ranged between 12.6 to 31.4 °C and 26 to 63 %, respectively during its previous week.

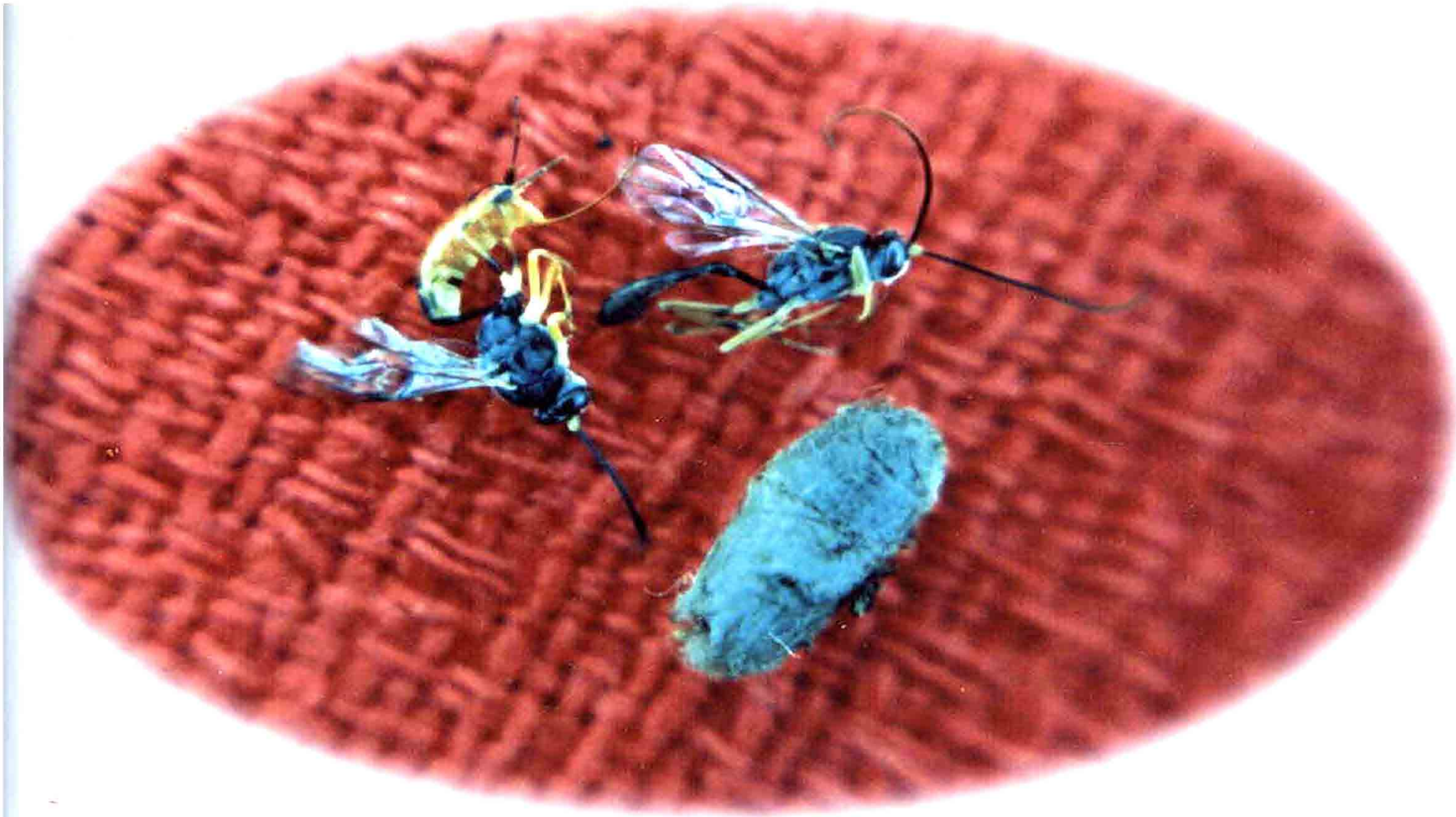

Plate 7. Pupa and Adults of *C. chlorideae,* a larval parasitoid of *H. armigera*

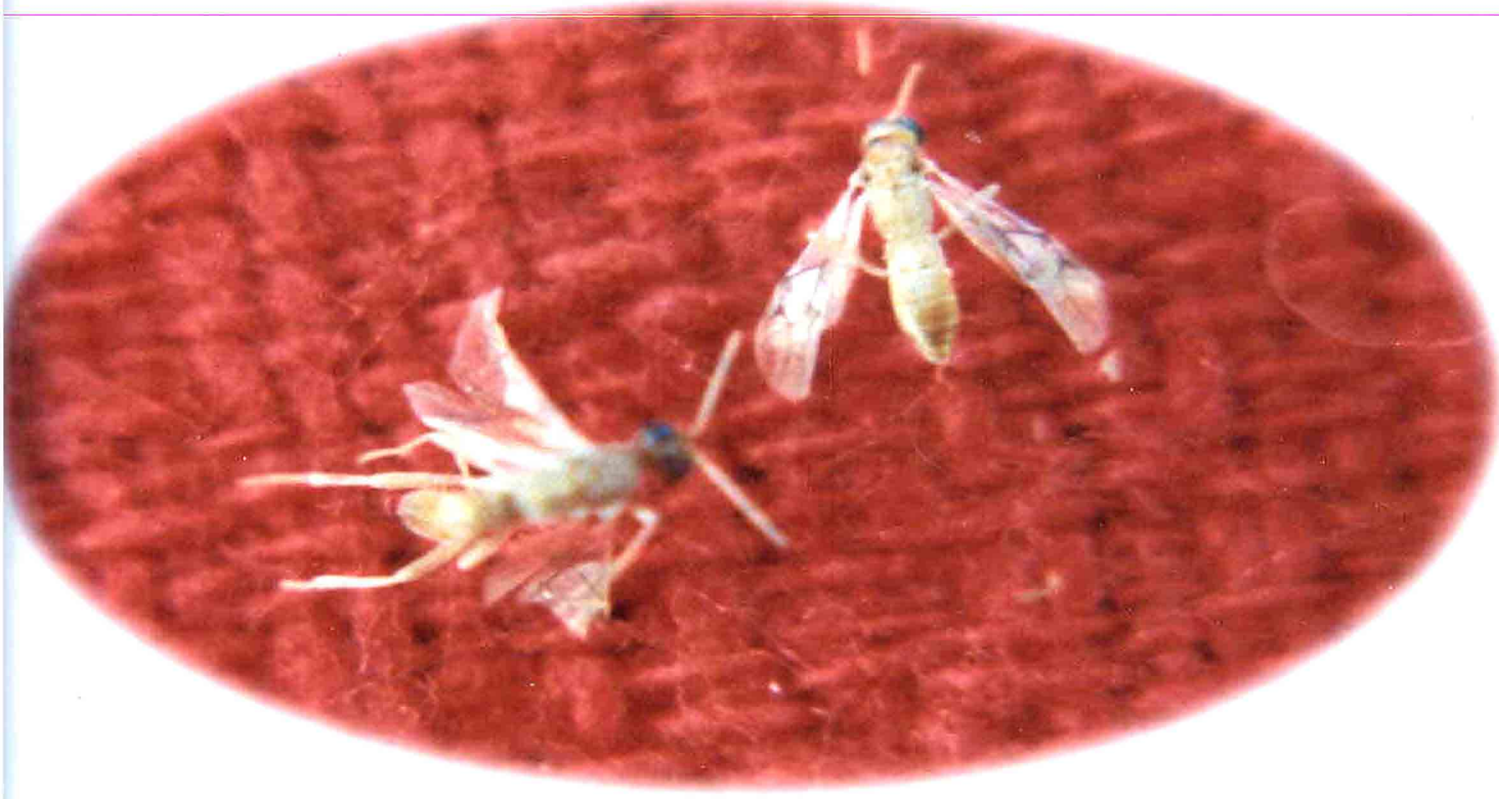

Plate 8. Adults of Eriborus *sp.,* laral parasitoid of *H. armigera*

During 2004-05 the highest parasitization due to *C. chlorideae*, *Eribrus sp* and both of them were recorded in 48th meteorological week i.e. 24, 12 and 36 per cent, respectively. The temperature and humidity ranged between 12.9 to 32.0 °C and 22 to 66 %, respectively.

4.3.3 Correlation studies

Perusal of values in Table 19 revaled that significant positive correlation between field parasitization and the larval population of the pests.

Mean maximum and minimum temperature as well as morning and evening humidity exhibited positive correlation with the larval population which were not significant.

Field parasitization showed positive and non-significant correlation with maximum temperature, minimum temperature and morning humidity. Whereas, it showed negative but non-significant correlation with evening humidity.

Table 19 : Relationship between larval population, field parasitization and weather parameter

Sr. No.	Particulars	Larval population	Field parasitization
1	Larval Population	--	0.777*
2	Maximum temperature	0.387	0.115
3	Minimum temperature	0.320	0.118
4	Morning humidity	0.230	0.181
5	Evening humidity	0.009	-0.079

* - Significant at 5 % level

4.4 Effect of malic acid on larval and pupal development of *H. armigera*

Data regarding the effect of feeding malic acid fortified, water washed and untreated chickpea leaves on larval and pupal development of *H. armigera* during 2003-04 and 2004-05 are presented in Table-20 and Table-21, respectively. All the three feeding methods did not show any significant effect on development of various stages of *H. armigera* during both the years.

During 2003-04, larvae reared on malic acid fortified chickpea leaves took 4.4 ± 0.66, 6.9 ± 0.54, 5.4 ± 0.49, 3.0 ± 0.00, 5.4 ± 1.02 and 5.3 ± 0.90 days for completion of 1st, 2nd, 3rd, 4th, 5th and 6th larval instars, respectively. Whereas larvae reared on water washed and untreated chickpea leaves took 4.9 ± 0.94, 6.9 ± 0.46, 5.1 ± 0.30, 3.1 ± 0.30, 4.7 ± 0.78, 5.4 ± 0.80 and 4.7 ± 0.78, 6.9 ± 1.04, 5.5 ± 0.81, 3.3 ± 0.46, 4.9 ± 1.22 and 6.8 ± 0.87 days for completion of 1st, 2nd, 3rd, 4th, 5th and 6th larval instars, respectively.

Total larval period was recorded shortest when larvae were reared on water washed chickpea leaves i.e. 29.9 ± 1.30 days wereas, it was longest (32.1 ± 1.22) when they were reared on untreated chickpea leaves. The larvae reared on malic acid fortified chickpea leaves took 30.4 ± 1.36 days for completion of larval stage. The pre-pupal and pupal period recorded in malic acid fortified, water washed and untreated chickpea leaves were 3.1 ± 0.54 and 16.9 ± 1.45 ; 3.3 ± 0.46 and 16.9 ± 0.94 and 3.2 ± 0.60 and 17.4 ± 1.20 days, respectively.

Similarly, during 2004-05 the larvae reared on malic acid fortified chickpea leaves took on an average 3.6 ± 0.75, 4.3 ±0.81, 4.0 ± 0.63, 2.5 ± 0.50, 5.0 ± 1.10 and 5.3 ± 1.04 days for completion of 1st, 2nd, 3rd, 4th, 5th and 6th instars respectively. However larvae reared on water washed and untreated chickpea leave took on an average 4.1 ± 0.86 ; 4.8 ± 0.14 ; 4.2 ± 0.14 ; 2.9 ± 0.54 ; 4.7 ± 0.78 ; 5.2 ± 0.60 and 4.2 ± 0.87 ; 5.3 ± 0.46 ; 4.6 ± 0.66 ; 3.1 ± 0.70 ; 4.8 ± 0.75 ; 5.9 ± 0.70 days for completion of 1st, 2nd, 3rd, 4th, 5th and 6th instars, respectively.

Shortest larval, pre-pupal and pupal period were recorded when larvae were reared on water washed chickpea leaves i.e. 25.9 ± 1.22, 2.9 ± 0.54 and 15.7 ± 0.90

Table 20 : Effect of feeding malic acid fortified, water washed and untreated chickpea leaves on larval and pupal development of *H. armigera* during 2003-04

Feeding Methods	*Mean number of days required to complete								
	Different Larval instars						Other stages		
	I	II	III	IV	V	VI	Total Larval period	Pre pupa	Pupa
M_1	4.4 ± 0.66	6.9 ± 0.54	5.4 ± 0.49	3 ± 0.00	5.4 ± 1.02	5.3 ± 0.90	30.4 ± 1.36	3.1 ± 0.54	16.9 ± 1.45
M_2	4.9 ± 0.94	6.7 ± 0.46	5.1 ± 0.30	3.1 ± 0.30	4.7 ± 0.78	5.4 ± 0.80	29.9 ± 1.30	3.3 ± 0.46	16.9 ± 0.94
M_3	4.7 ± 0.78	6.9 ± 1.04	5.5 ± 0.81	3.3 ± 0.46	4.9 ± 1.22	6.8 ± 0.87	32.1 ± 1.22	3.2 ± 0.60	17.4 ± 1.20
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
S.E. m ±	0.22	2.91	2.24	1.32	2.20	2.40	12.97	1.38	7.17

* - Mean of 10 larvae

M_1 - Feeding with malic acid fortified chickpea leaves

M_2 - Feeding with water washed chickpea leaves

M_3 - Feeding with untreated chickpea leaves

Table 21 : Effect of feeding malic acid fortified, water washed and untreated chickpea leaves on larval and pupal development of *H. armigera* during 2004-05.

Feeding Methods	*Mean number of days required to complete								
	Different Larval instars						Other stages		
	I	II	III	IV	V	VI	Total Larval period	Pre pupa	Pupa
M_1	3.6 ± 0.75	4.3 ± 0.81	4.0 ± 0.63	2.5 ± 0.50	5.0 ± 1.10	5.3 ± 1.04	27.5 ± 2.16	3.0 ± 0.63	15.8 ± 1.40
M_2	4.1 ± 0.83	4.8 ± 0.40	4.2 ± 0.40	2.9 ± 0.54	4.7 ± 0.78	5.2 ± 0.60	25.9 ± 1.22	2.9 ± 0.54	15.7 ± 0.90
M_3	4.2 ± 0.87	5.3 ± 0.46	4.6 ± 0.66	3.1 ± 0.70	4.8 ± 0.75	5.9 ± 0.70	27.9 ± 1.64	3.2 ± 0.75	16.2 ± 1.08
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS
S.E. m ±	1.77	2.14	1.83	1.27	2.14	2.41	11.40	1.34	6.70

* - Mean of 10 larvae

M_1 - Feeding with malic acid fortified chickpea leaves

M_2 - Feeding with water washed chickpea leaves

M_3 - Feeding with untreated chickpea leaves days, respectively. Whereas, larvae reared on untreated chickpea leaves registered longest larval (27.9 ± 1.64), pre-pupal (3.2 ± 0.75) and pupal (16.2 ± 1.08) period. Feeding with malic acid fortified chickpea leaves required 27.5 ± 2.16 ; 3.0 ± 0.63 and 15.8 ± 1.40 days for completion of larval, pre-pupal and pupal period.

CHAPTER – V

DISCUSSION

CHAPTER – V

DISCUSSION

The experimental findings of the present investigation, described in the earlier chapter have been discussed in the forgoing pages in the light of available relevant literature under respective subheadings.

5.1 Evaluation of microbial insecticides either alone or their combinations

5.1.1 Effect of various treatments on larval population of *H. armigera*

5.1.1.1 Larval population of *H. armigera*, three days after first spray

The results on larval population of *H. armigera*, three days after first spray, during both the years of experimentation as well as their pooled analysis revealed more or less similar trend of efficacy due to various treatments against this pest. Amongst various treatments spinosad (0.01 %) and endosulfan (0.06%) were statistically at par and significantly superior over other treatments.

The remaining treatments viz., *Helicoverpa armigera* nuclear polyhedrosis virus (250 LE / ha), *Bacillus thuringiensis* (750 LE / ha), *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) + *Bacillus thuringiensis* (375 ml / ha), *Metarhizium anisopliae* (2.5 kg / ha), *Beauveria bassiana* (2.5 kg / ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) and *Beauveria bassiana* (1.25 kg / ha)+ *Bacillus thuringiensis* (375 ml / ha) prouced more or less similar effects but were significantly superior over untreated control.

Present findings regarding significant superiority of spinosad and endosulfan over HaNPV and Bt, three days after spraying are almost in accordance with those of Dhonde *et al.* (2005) who reported that spinosad (75 g a.i. / ha) was significantly superior over HaNPV (250 LE / ha) in reucing the larval population of *H. armigera* 72 hours after spraying and was at par with endosulfan (350 g a.i. / ha) and Bt (1000 g / ha). Similar results regarding endosulfan are reported by Rabindra *et al.*(1991). They have recorded significantly less larval population (3.7 / 5 plants) in endosulfan(350 g a.i. / ha) than nuclear polyhedrosis virus (250 LE / ha) at three days after first spray. Supare *et al.*(1991) also reported significantly more larval reduction in endosulfan (0.07 %) than HNPV (250 LE / ha) at four days after spraying. Similarly, Ramteke *et al.*(2002) have also registered significantly less larval population (8.05 / 10 plants) in endosulfan than HaNPV and Bt.

Sidde Gowda and Suhas Yelshetty (2005) reported at par larval population with delfin (1500 g / ha), basina (5000 g / ha), HaNPV (250 LE / ha) and endosulfan (1000 ml / ha) but were significantly superior over untreated check at three days after first spray. These findings strongly supported the present finding regarding equal effectiveness of HaNPV, Bt and *Beauveria bassiana*. However, their findings regarding endosulfan are not in accordance with present findings.

Further, Phadtare *et al.* (2004) have reported Bt (2 g / l) and its combination with *Beauveria bassiana* (1.2 X 10^5 spores / ml) as well as HaNPV (2 X 10^9 PIBS / ml) and its combination with *Beauveria bassiana* (1.2 X 10^5 Spores / ml) produced statistically equal larval mortality at three days after treatment under laboratory condition. These findings are in line with present findings except the significantly superior performance of Bt and its combination with *Beauveria bassiana* than HaNPV and its combination with *Beauveria bassiana* which is not in accordance with present findings. Efficacy of *Metarhizium anisopliae* and its combination with HaNPV and Bt could not be compared for want of related literature.

5.1.1.2 Larval population of *H. armigera*, seven days after first spray

Based on two years results as well as pooled analysis, spinosad (0.01 %) and endosulfan (0.06 %) did not differ statistically and proved consistently superior over rest of the treatments. These two treatments were followed by *Helicoverpa armigera* nuclear polyhedrosis virus (250 LE / ha), *Bacillus thuringiensis* (750 ml / ha) and *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) + *Bacillus thuringiensis* (375 ml / ha).

Treatments *Metarhizium anisopliae* (2.5 kg / ha), *Beauveria bassiana* (2.5 kg / ha) and their combination viz., *Metarhizium anisopliae* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE /ha) and *Beauveria bassiana* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha) were almost statistically at par but significantly superior over untreated control.

Dhonde *et al.* (2005) reported superiority of spinosad (75 g a.i. / ha) and endosulfan (350 g a.i. / ha) over Bt (1000 g / ha) and HaNPV (250 LE / ha) seven days after spraying against same pest on the same crops similarly the superiority of spinosad was also reported by Dandale *et al.*(2000) and Saindane (2002) against same pest at same interval but on cotton.

The findings regarding equal effectiveness of HaNPV, Bt and their combination at half doses are in accordance with Loganathan *et al.* (2000). During their work spicturin (1.0 l / ha), HaNPV (1.5 X 10^{12} POB / ha) have registered statistically equal larval population seven days after treatment. Similar type of results were also found by Srinivisan *et al.* (1994). However, Bhatt and Patel (2002) reported that the combination of HaNPV and Bt was significantly superior then their individual applications which is differing from the present findings.

As regards the efficacy of fungal pathogens against *H. armigera*, Shivramkrish.na (2004) reported that *Metarhizium anisopliae* was more effective than *Beauveria bassiana* against same pest on chickpea. He further reported that these fungal pathogens were not as effective as endosulfan (0.07 %), HaNPV (250 LE / ha) and Bt (750 ml / ha). The trend of efficacy recorded by him is in full conformity with the trend obtained in the present investigations.

Combination of *Metarhizium anisopliae* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE /ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + *Helicoverpa armigera* nuclar polyhedrosis virus (125 LE / ha) and *Beauveria bassiana* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha) were found least effective during both the years at both the intervals and their poole effect. These results could not be compared with the earlier work due to its non availability in the literature.

It appeared that the spinosad has been tested for the first time against *H. armigera* on chickpea during the present studies. However, results obtained during present studies are fully supported by those obtained by Dandale *et al.* (2000) who reported that spinosad (75 and 50 g a.i. / ha) was most effective in controlling the infestation of *H. armigera* in green fruiting bodies of cotton at fourteen days after treatment. Similar type of results were also reported by Saindane (2002) against same pest on Cotton.

The present findings regarding the efficacy of endosulfan ten and fourteen days after spraying are quite comparable with Pawar *et al.* (1987), Datkhile *et al.* (1996), Ravi and Verma (1997a) and Bhalkare (2000) who clearly reported the significant superiority of endosulfan over biopesticides.

Equal effectiveness of HaNPV, *Metarhizium anisopliae*, *Beauveria bassiana* and *Bacillus thuringiensis* found in present investigations is in confirmity with the results reported by Pharindera Yadav *et al.* (2005) who reported equal larval population of *H. armigera* with delfin (1 kg / ha), basina (1 kg / ha) and HaNPV (250 LE / ha) at eleven and fourteen days after treatment. However, they have also reported that these treatments did not differ from endosulfan (0.07 %) which is not in tune with present findings. Equal efficacy of Bt and HaNPV at fourteen days after treatment is also reported by Ramtake *et al.* (2002).

Almost similar type of effectivity of fungal pathogens was also reported by Pharindera Yadav *et al.* (2005) and Kulkarni *et al.* (2005) which strengthened the findings related to fungal pathogens in the present study. However, Sidde Gowda and Suhas Yelshetty (2005) reported lower larval population of *H. armigera* in the treatment with Basina (5000 g / ha) than delfin (1500 g / ha), HaNPV (250 LE / ha) and endosulfan (1000 ml / ha) at seven days after first spray which is not in accordance with present findings. The lower larval population recorded in basina might be due to application of very high dose (5000 g / ha) of basina.

The findings regarding efficacy of half doses of *Metarhizium anisopliae* and *Beauveria bassiana* in combination with the half doses of HaNPV and Bt can not be discussed because of non availability of literature.

5.1.1.3 Larval population of *H. armigera*, ten and fourteen days after first spray

Consistently lowest larval population was recorded in treatments with spinosad (0.01 %) and endosulfan (0.06 %) during both the years at both the intervals as well as their pooled effects.

Another group of better treatments consisted HaNPV (250 LE /ha), *Metarhizium anisopliae* (2.5 k g/ ha), *Beauveria bassiana* (2.5 kg / ha), *Bacillus thuringiensis* (750 ml / ha) and *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) + *Bacillus thuringiensis* (375 ml / ha) which exhibited more or less similar performance during indivisual years at both the intervals as well as their pooled effects.

Efficacy of *Metarhizium anisopliae* during this study is quite comparable with Kulkarni *et al.*(2005) who reported that *Metarhizium anisopliae* (2 g / lit.) was as effective as *Bacillus thuringiensis* (2 ml / lit.) in reducing *H. armigera* larvae fifteen days after spraying on chickpea. However, Shivramkrishna (2004) reported significant superiority of endosulfan (0.07 %), HaNPV (250 LE / ha) and *Bacillus thuringiensis* (750 ml / ha) over *Metarhizium anisopliae* (10^{10} and 10^{8} spores / ml) and *Beauveria bassiana* (10^{10} and 10^{8} spores / ml) at fourteen days after spraying which is not in accordance with the present findings. However, the trend of efficacy obtained by him is comparable with the present findings.

Less efficacy of combined application of HaNPV and Bt at half doses than their indivisual applications found strong support in the work by Tustin *et al.* (1994).

Least effictivity of fungal pathogens in combination with HaNPV and Bt at half doses might be due to their insufficient dose than required to bring higher mortality coupled with the absence of complementary action between these microbial preparations. However, no work relating to this fact could be ascertained from the literature.

5.1.1.4 Larval population of *H. armigera*, three days after second spray

The experimental findings of both the years and their pooled analysis indicated that all the treatments followed more or les similar trend of efficacy against the larvae of *H. armigera*, three days after second spray. Among the various treatments, spinosad (0.01 %) and endosulfan (0.06%) found significantly superior over rest of treatments and were followed by *Bacillus thuringiensis* (750 ml / ha), *Helicoverpa armigera* nuclear polyhedrosis virus (250 LE / ha) and *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) + *Bacillus thuringiensis* (375 ml / ha).

Treatments *Metarhizium anisopliae* (1.25 kg / ha) and *Beauveria bassiana* (1.25 kg / ha) were less effective but recorded less larval population than combination of *Metarhizium anisopliae* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) and *Beauveria bassiana* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha).

Dhonde *et al.* (2005) reported equal effectiveness of spinosad and endosulfan three days after spraying against *H. armigera* on chickpea.

Whereas, the work carried by Rabindra *et al.* (1991), Bhalkare (2000) and Bhatt and Patel (2002) clearly indicated the significant superiority of endosulfan over biopesticides against *H. armigera* on chickpea at three days after second spraying.

Equal efficacy of HaNPV, Bt and their combination observed at three days after second spraying get strong support of the work carried out by Lognathan *et al.* (2000) at Sarvanampatti. It can further be strengthened by Men (1992) who also observed similar reaction with these two microbial insecticides while working on *Thysanoplusia orichalcea* on Sunflower.

However, Bhatt and Patel (2002) reported significantly superior performance of combination of these two microbial insecticides than their indivisual applications.

The findings regarding trend of efficacy of *Metarhizium anisopliae* and *Beauveria bassiana* is quite comparable with those of Shivramkrishna (2004), Pharindera Yadav *et al.* (2005) and Kulkarni *et al.* (2005).

Phadtare *et al.* (2004) reported that combinations of Bt (2 g / lit.) + *Beauveria bassiana* (1.2 X 10^5 spores / ml) and HaNPV (2 X 10^5 PIB / ml) + *Beauveria bassiana* (1.2 X 10^5 spores / ml) were little more effective than individual application of Bt (2 g / l) and HaNPV (2 X 10^9 PIB / ml). This might be due to application of full dose of these microbials in the combinations. The findings regarding efficacy of *Metarhizium anisopliae* + HaNPV and *Metarhizium anisopliae* + Bt could not be compare because of non availability of literature.

5.1.1.5 Larval population of *H. armigera*, seven days after second spray

Consistently superior performance was recorded by treatments with spinosad (0.01 %) and endosulfan (0.06 %) during both the years and their combine effect.

Another group of better treatments consisted of *Helicoverpa armigera* nuclear polyhedrosis virus (250 LE / ha), *Bacillus thuringiensis* (750 ml / ha), *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) + *Bacillus* *thuringiensis* (375 ml / ha), *Metarhizium anisopliae* (2.5 kg / ha) and *Beauveria bassiana* (2.5 kg / ha) which exhibited similar performance during individual years as well as their pooled effects.

Combinations of *Metarhizium anisopliae* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) and *Beauveria bassiana* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha) were found least effective during both the years and their pooled effect.

Information on testing of spinosad against *H. armigera* on chickpea is lacking. However, superiority of spinosad observed in present study could be compare with the earlier work of Dandale *et al.* (2000) and Saindane (2002) who reported that spinosad (50 g a.i. / ha) was effective in reducing the infestation of *H. armigera* on cotton seven days after spraying. Significant superiority of endosulfan seven days after second spraying as revealed in the present work was also reported by many workers viz., Pawar *et al.*(1987), Bhalkare (2000) Bhatt and Patel (2002) and Sing and Yadav (2005). However, Sidde Gowda and Suhas Yelshetty (2005) reported equal effectiveness of endosulfan (1000 ml / ha) with delfin (1500 g / ha), basina (5000 g / ha) and HaNPV (250 LE / ha) at seven days after second spraying which might be due to higher dosages used by them.

Pawar *et al.* (1987) and Sarode *et al.* (1993) reported significant superiority of HNPV against *H. armigera* on chickpea at seven days after spraying. Bhalkare (2000) reported that HaNPV (250 LE / ha) and Bt (1 lit. / ha) were equally effective and stood next to endosulfan (0.07 %) in reducing larval population of *H. armigera* seven days after second spray. Loganathan *et al.*(2000) reported equal effectiveness of spicturine (1.00 l / ha), HaNPV (1.5 X 10^{12} POB / ha) and spicturing (1.0 l / ha) + HaNPV (1.5 X 10^{12} POB / ha) at seven days after second spray. Bhatt and Patel (2002) found that HaNPV (250 LE / ha) and Bt (1 kg / ha) were equally effective and stood next to the endosulfan (0.07 %) in recording mean per cent larval mortality at 1 week after second spray. All these findings strongly support the present findings regarding HaNPV, Bt and their combination.

However, efficacy of *Metarhizium anisopliae*, *Beauveria bassiana* and their combinations could not be discussed due to non-availability of similar literature.

5.1.1.6 Larval population of *H. armigera*, ten and fourteen days after second spray

The results on the larval population of *H. armigera* ten and fourteen days after second spray during both the years of field trials and when pooled together showed more or less similar trend of efficacy with various treatments. Treatment with spinosad (0.01 %) was found most effective and did not differ significantly from endosulfan (0.06%).

The next effective group of treatments consisted of *Helicoverpa armigera* nuclear polyhedrosis virus (250 LE / ha), *Metarhizium anisopliae* (2.5 kg /ha), *Beauveria bassiana* (2.5 kg / ha) and *Bacillus thuringiensis* (750 ml / ha). The combined applications of these treatments viz., *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) + *Bacillus thuringiensis* (375 ml / ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) and *Beauveria bassiana* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha) were least effective but were significantly superior over untreated control at both the intervals and at both the years as well as their pooled effect.

The results regarding the efficacy of endosulfan over HaNPV could be compared with those of Pawar *et al.*(1987) who reported significantly less larval population of *H. armigera* in endosulfan (0.05 %) than HNPV (250 LE / ha) at fourteen days after second spraying. Similarly Bhalkare (2000) also reported significant superiority of endosulfan (0.07 %) over HaNPV (250 LE / ha) and Bt (1 lit. / ha) which produced equal effect at fourteen days after second spray.

The findings regarding the efficacy of other treatments could not be compared because of non availability of literature on similar type of work specially on chickpea. However, Dandale (2000) reported that spinosad (75 and 50 g a.i. / ha) was most effective in controlling the infestation of *H. armigera* on cotton fourteen days after treatment. Efficacy of spinosad against *H. armigera* was also reported by Saindane (2002) on cotton, Jesmi Vijayan (2005) on tomato and Gaikwad and Bhamare (2006) on cotton.

Similarly, the equal efficacy of fungal pathogens, HaNPV and Bt observed in the present work could be compared with the results reported by Pharindera Yadav *et al.*(2005) and Kulkarni *et al.*(2005).

The lower efficacy of combined application of HaNPV and Bt at half doses over their individual applications found support with the work carried by Srinivisan *et al.* (1994), Tustin *et al.* (1994) and Loganathan *et al.* (2000).

Phadtare *et al.* (2004) reported that combined application of HaNPV (2 X 10^9 PIB / ml) + *Beauveria bassiana* (1.2 X 10^8 spores / ml) is less effective than individual application of HaNPV (2 X 10^9 PIB / ml) which is in accordance with present findings. However their findings regarding equal effectiveness of Bt (2 g /

l) with Bt (2 g / l) + *Beauveria bassiana* (1.2 X 10^5 spores / ml) and lower efficacy of *Beauveria bassiana* (1.2 X 10^5 spores / ml) alone are in contradiction to present findings. The reason for getting higher mortality incombined application of Bt + *Beauveria bassiana* might be due to use of full doses in combination.

5.1.2 Effect of various treatments on grain yield of chickpea

The year-wise grain yield of chickpea as well as their pooled data revealed that maximum yield was harvested from the plots treated with spinosad (0.01 %) which did not differ from endosulfan (0.06 %).

The treatments viz., *Helicoverpa armigera* nuclear polyhedrosis virus (250 LE / ha); *Bacillus thuringiensis* (750 ml / ha) and *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha) + *Bacillus thuringiensis* (375 ml / ha) from the next effective group producing better grain yield and were followed by *Metarhizium anisopliae* (2.5 kg / ha) and *Beauveria bassiana* (2.5 kg / ha).

Treatments, *Metarhizium anisopliae* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha), *Beauveria bassiana* (1.25 kg / ha) + *Helicoverpa armigera* nuclear polyhedrosis virus (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha) and *Beauveria bassiana* (1.25 kg / ha) + *Bacillus thuringiensis* (375 ml / ha) harvested less grain yield but were significantly higher than untreated control.

The present findings regarding highest grain yield of chickpea harvested from spinosad and endosulfan are in accordance with Dhonde *et al.* (2005). Similarly, Gaikwad and Bhamare (2005) also recorded highest seed yield of cotton from spinosad (50 g a.i. / ha) which did not differ from that of endosulfan (300 g a.i. / ha). Efficacy of endosulfan in producing significantly highest grain yield of chickpea is also reported by various workers viz., Pawar *et al.* (1987), Pawar *et al.*

(1990), Datkhile *et al.* (1996), Shukala *et al.* (1996), Vyas and Lakhchaura (1996), Ujagir *et al.* (1997), Bhalkare (2000) and Pharindera Yadav *et al.* (2005).

Equal grain yield harvested from HaNPV, Bt and their combinations could be compared with Loganathan *et al.* (2000) and Bhatt and Patel (2002). Equal grain yield of chickpea from the plots treated with HaNPV and Bt is also supported by Pawar *et al.* (1999) and Pharindera Yadav (2005) Sidde Gowda and Suhas Yelshetty (2005).

The yield obtained from *Metarhizium anisopliae* and *Beauveria bassiana* treated plots could be compared with Shivramkrishna (2004), who also observed same trend in producing higher grain yield from the mycoinsecticides. Similar results in case of *Beauveria bassiana* were also reported by Pharindera Yadav *et al.* (2005) Sidde Gowda and Suhas Yelshetty (2005).

The yield obtained from the plots treated with combined application of *Metarhizium anisopliae* with HaNPV or Bt and *Beauveria bassiana* with HaNPV or Bt could not be compared because of want of literature on this aspect.

5.1.3 Incremental cost benefit ratio of various treatments

The results on incremental cost benefit ratio of various treatments during both the years as well as their pooled results showed that endosulfan @ 0.06 % was economically most viable followed by *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha, *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha + *Bacillus thuringiensis* @ 375 ml / ha, *Bacillus thuringiensis* @ 750 ml / ha and spinosad @ 0.01 %.

The treatments *Beauveria bassiana* @ 2.5 kg / ha and *Metarhizium anisopliae* @ 2.5 kg / ha were economically less effective but were economically more viable than the treatment combinations viz., *Metarhizium anisopliae* @ 1.25

kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Beauveria bassiana* @ 1.25 kg / ha + *Helicoverpa armigera* nuclear polyhedrosis virus @ 125 LE / ha, *Metarhizium anisopliae* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha and *Beauveria bassiana* @ 1.25 kg / ha + *Bacillus thuringiensis* @ 375 ml / ha.

Present trend of economic ranking of treatments viz., endosulfan, HaNPV, HaNPV + Bt and Bt is in conformity with Bhatt and Patel (2002) who also reported that endosulfan @ 0.07 % was economically most viable and followed by HaNPV @ 250 LE / ha, HaNPV @ 125 LE / ha + Bt @ 0.5 kg / ha and Bt @ 1 kg / ha. However, they reported that Bt was uneconomical due to his high cost. Somewhat similar trend of efficacy was also reported by Loganathan *et al.* (2000) at Sarvanampatti where they found that HaNPV @ 1.5 X 10^{12} POB / ha was most economical and was followed by spicturin 1.00 lit. / ha + HaNPV @ 1.5 X 10^{12} POB / ha and spicturin 1.00 lit / ha. More economic viability of endosulfan over HaNPV and Bt was also reported by Datkhile *et al.* (1996), Wanjari *et al.* (1998) and Ramtake *et al.* (2002).

In present study, spinosad although recorded highest grain yield but economically ranked 5th after endosulfan, HaNPV, HaNPV + Bt and Bt due to its high cost. Similar results was also reported by Dhonde *et al.* (2005) on chickpea and Gaikwad and Bhamare (2006) on cotton.

Less economical viability of fungal pathogens viz., *Metarhizium anisopliae* and *Beauveria bassiana* observed during present study find support in the work by Undirwade *et al.* (2004) against same pest on pigeon pea. However, Sidde Gowda and Suhas Yelshetty (2005) found that basina @ 500 g / ha was economically more superior than delfin @ 1500 g / ha, this may be due to different doses of insecticides used in thir investigation.

The present finding regarding least economic viability of combined application of fungal pathogens with HaNPV or Bt could not be compared because of non availability of literature.

5.2 Evaluation of different modules against *H. armigera* on chickpea

5.2.1 Effect of various modules on larval population of *H. armigera*

The results on cumulative average larval population of *H. armigera* in different modules, during both the years of experimentation as well as their pooled analysis revealed more or less similar trend of efficacy against this pest. All the modules evaluated recorded significantly less larval population than control. Amongst the various modules tested, module M_7 consisted of three sprays of endosulfan @ 0.06 % recorded least larval population and did not differ from module M_5 comprising *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha- spinosad @ 0.01 %.

These two modules were followed by module M_2 (*Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha -- endosulfan @ 0.06 %), M_6 (spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha) and M_3 (endosulfan @ 0.06 %- *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha).

However, module M_1 having *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha and module M_4 with Neem Seed Kernel Entract @ 5% - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha were less effective and recorded comparatively more larval population than other modules during both the years and their pooled results.

The present finding regarding superiority of application of chemical insecticide (3 sprays of endosulfan) could be compared with those of Kumawat and Zheeba (1999) who reported alternate application of monocrotophos and endosulfan as most effective.

Similarly, the present finding regarding efficacy of module M_2 having first two sprays of biopesticides (Bt and HaNPV) followed by third spray of endosulfan could be compared with the results obtained by Sanap and Pawar (1998) who reported that modules with first two sprays of biopesticides (either NPV or NSKE) followed by third spray of endosulfan were most effective against *H. armigera* on chickpea. Similarly, Singh *et al.* (2000) also found that modules consisted of HaNPV @ 250 LE / ha – Btk @ 1500 ml / ha – endosulfan @ 1250 ml / ha was most effective against same pest on same crop.

Similarly, present findings regarding significantly less larval population recorded in module M_1 (Bt – HaNPV- Bt) than control is in line with the study conducted at TNAU, Coimbatore (Annonymous, 2003c) who also reported significantly less larval population of *H. armigera* in almost similar type of module.

Results regarding efficacy of modules consisted of spinosad could not be compared with earlier work because of not availability of literature.

5.2.2 Effect of various modules on grain yield of chickpea

The results regarding grain yield of chickpea as influence by various modules showed more or less same trend of efficacy during both the years of field trials and when pooled together. Module M_7 with 3 sprays of endosulfan @ 0.06 % produced highest grain yield and was statistically at par with module M_5 consisted of *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha – spinosad @ 0.01 % and module M_2 having *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha – endosulfan @ 0.06 %.

Module M_6 having spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha and module M_3 having endosulfan @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha were moderately effective but produced more grain yield than module M_1 consisted of *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 ml / ha and module M_4 comprising of neem seed kernel extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha and *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha.

Equal grain yield obtained in module with 3 sprays of endosulfan and module consisted of first two sprays of biopesticides (Bt and HaNPV) followed by third spray of endosulfan could be compared with Sanap and Pawar (1998) who also harvested equal grain yield from plants treated with three sprays of endosulfan and those treated with first two sprays of bio pesticides (NPV or NSKE) followed by third spray of endosulfan. Similarly, Sing *et al.* (2000) also obtained more grain yield from module consisted of HaNPV – Bt – endosulfan. Similar results were also obtained by Khajuria *et al.* (2006) against same pest on tomato.

Similarly, present findings regarding significantly higher grain yield harvested from module M_1 (Bt - HaNPV – Bt) than control could be compare with the findings of Annonymous, (2003 C) who also harvested significantly more grain yield of chickpea from Bt – HaNPV – Bt - HaNPV alternations than control. However, efficacy of modules consisted of spinosad could not be discussed as no work on these lines could be detected from the literature searched.

5.2.3 Incremental cost benefit ratio of various modules

Incremental cost benefit ratio of various modules during both the years and their pooled results showed that module consisted of three sprays of endosulfan @ 0.06 % was economically most viable giving highest cost benefit ratio and was followed by module M_2 consisted of *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha – endosulfan @ 0.06 % and module M_3 comprising of endosulfan @ 0.06 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha.

Module M_4 having neem seed kernel extract @ 5 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha an module M_5 with *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha – spinosad @ 0.01 % gave better returns and was followed by module M_1 having *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha - *Bacillus thuringiensis* @ 750 LE / ha. Module M_6 comprising of spinosad @ 0.01 % - *Bacillus thuringiensis* @ 750 ml / ha - *Helicoverpa armigera* nuclear polyhedrosis virus @ 250 LE / ha was economically least effective.

Present finding regarding highest ICBR obtained in module with three sprays of endosulfan @ 0.06 % could be compared with that obtained by Sanap and Pawar (1998) and Kumawat and Jheeba (1999). Similarly, present findings regarding economical viability of module M_2 consisted of Bt – HaNPV - endosulfan and M_3 having endosulfan - Bt - HaNPV over modules M_4 (NSKE – Bt – HaNPV) and M_1 (Bt – HaNPV – Bt) is also supported by the work by Sanap and Pawar (1998) and Sing *et al.* (2000) who found that modules with two sprays of biopesticides and one spray of endosulfan were economically superior than those having all the three sprays of biopesticides.

Economic viability of modules comprising spinosad could not be compared with earlier work because of non availability of similar type of literature. However, least ICBR obtained from these modules was due to very high cost of spinosad.

5.3 Relationship between larval population of *H. armigera*, its field parasitization and weather parameters

5.3.1 Seasonal incidence of *H. armigera*

During both the years of study incidence of *H. armigera* was noticed one month after sowing. It then gradually increased and reached its peak during 49th and 50th meteorological week during 2003-04 with maximum and minimum temperature variation of 16.5 to 32.2 and 11.9 to 31.2 ^{o}C while relative humidity between 30 to 77 % and 21 to 64 %, respectively during the preceding weeks. During 2004-05 peak incidence of pest was observed in 48th meteorological week with temperature between 12.9 to 32.0 ^{o}C and relative humidity between 22 to 66% during its preceding week. It then gradually decrease and was minimum at the time of harvesting.

Peak activity of pest observed between 48th to 50th meteorological week in the present study are in line with study by Yadava and Lal (1985) who also observed peak activity of this pest on chickpea during 47th and 50th meteorological weeks. Likewise, Yadava *et al.* (1991) also observed peak activity of pest during 47th – 51st meteorological weeks. Similarly, Patel and Koshiya (1999) observed the highest incidence of pest during 3rd week of December which is quite in accordance with present findings.

Vaishampayan and Veda (1980) observed that relative humidity below 75% during major active period from December to February gave a clear indication of higher population build up of pest on gram which supported the present study as relative humidity was below 75 % at the time of peak incidence of pest during both the years.

- Similarly, an observation of Anwar and Shafique (1992) and Tomar and Sehgal (1993) that peak incidence of pest was associated with flowering and podding stages of crop were also in accordance with present findings.

5.3.2 Parasitization of the pest

During both the years of investigations no egg and pupal parasitoids was recorded from *H. armigera* eggs or pupae whereas, two parasitoids viz., *Compoletis chlorideae* and *Eriborus* sp were found parasitizing *H. armigera* larvae. Among these two larval parasitoids, *C. chlorideae* was most predominant with highest parasitization of 20 % in 50th meteorological week whereas, maximum parasitization (12 %) due to *Eriborous* sp was observed in 51st meteorological week during 2003-04. Total parasitization due to both the parasitoids was maximum in 51st meteorological week with temperature between 12.6 to 31.4 °C and relative humidity between 26 to 63 % during its previous week.

However, during 2004-05 the maximum parasitization due to *C. chlorideae* (24 %), *Eriborous* sp (10 %) and both parasitoids (36 %) was observed in 48th meterological week with temperature between 12.9 to 32.0 °C and relative humidity between 22 to 66 % during the preceeding week. No such detaliled work on this pest was available in the literature screened. Hence the present finding could not be compared. However, Bilapate (1981), Yadav *et al.* (1985), Srinivas (1989) and Sachan and Bhumik (1998), observed maximum parasitization in the month of December which is in accordance with present findings.

In the present study a larval parasitoids *C. chlorideae* was observed as most predominant and important mortality factor of *H. armigera* on chickpea during both the years of investigations. Similar observations were also made by Bilapate *et al.* (1979), Sithanantham *et al.* (1982), Patnaik *et al.* (1991) and Devi *et al.* (2002).

Present finding regarding absence of egg parasitoids in chickpea are in conformity with Yadav and Patel (1981), Yadav *et al.* (1982) and Kulat *et al.* (1999) who also reported ineffectiveness of egg parasitoids in chickpea due to acidic secretion produced by the leaves.

5.3.3 Correlations studies

During present study positive and significant correlation was observed between field parasitization and the larval population of the pest.

Similarly, mean maximum and minimum temperature as well as mean morning and evening humidity showed positive non-significant correlations with the larval population. Whereas, field parasitization showed positive non-significant correlation with maximum temperature, minimum temperature and morning humidity. While it showed negative and non-significant correlation with evening humidity.

The positive correlation observed between larval population and field parasitization during present study is in accordance with Vaishampayan and Veda (1980) and Devi *et al.* (2002). Similarly, Vaishampayan and Veda (1980), Yadav and Lal (1985), Yadav *et al.* (1991) and Metange *et al.* (2002) also observed the positive correlation between larval population and maximum and minimum temperature which is also in accordance with present findings. However, present findings of correlation studies between field parasitization and weather parameters could not be compared due to non-availability of similar report in the literature reviewed.

5.4 Effect of malic acid on larval and pupal development

Results regarding effect of feeding malic acid fortified chickpea leaves, water washed chickpea leaves and untreated chickpea leaves on larval and pupal development of *H. armigera* were non-significant suggesting that malic acid had no effect on larval and pupal development of *H. armigera*. Larvae reared by different feeding methods took on an average 29.9 ± 1.30 to 32.1 ± 1.22 and 25.9 ± 1.22 to 27.9 ± 1.64 days for completion of its larval stage during 2003-04 and 2004-05, respectively. Whereas it took 3.1 ± 0.54 to 3.3 ± 0.46 and 16.9± 0.94 to 17.4 ± 1.20 days and 2.9 ± 0.54 to 3.2 ± 0.75 days and 15.7 ± 0.19 to 16.2 ± 1.08 days for completion of per-pupal and pupal stages in different feeding methods during 2003-04 and 2004-05, respectively.

Present finding regarding non-significant effect of malic acid on larval and pupal development of *H. armigera* are strongly supported by Yoshida *et al.* (1995) who also reported that malic acid had no effect on larval growth of *H. armigera*. Whereas, total larval pre-pupal and pupal period observed during present study are quite comparable with Ghosh *et al.* (1986), Sharma and Chaudhari (1988) and Valand and Patel (1993)

CHAPTER – VI

SUMMARY

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SUMMARY

Field experiments were carried out during present study with a view to evaluate some microbial insecticides either alone or in combination, to evaluate some modules for bio-intensive modules of *Helicoverpa armigera* and to study the biotic complex and seasonal incidence of pest on chickpea. Beside these field experiments a laboratory study was also carried out to study the effect of malic acid on larval and pupal development of *H. armigera*.

To evaluate microbial insecticides and their combinations a field experiment was laid out in randomized block design with three replications and twelve treatments including control. Microbial insecticide such as *Metarhizium anisopliae* (2.5 kg / ha), *Beauveria bassiana* (2.5 kg / ha), HaNPV (250 LE / ha), Bt (750 ml / ha) and their combinations at half doses viz., *Metarhizium anisopliae* (1.25 kg / ha) + HaNPV (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + Bt (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + HaNPV (125 LE / ha), *Beauveria bassiana* (1.25 kg / ha) + Bt (375 ml / ha) and HaNPV (125 LE / ha) + Bt (375 ml / ha) were evaluated against standard check endosulfan (0.06 %) and new molecule spinosad (0.01 %).

Similarly, other field experiments were also laid out in randomized block design with three replications for evaluation of different module for bio-intensive management of *H. armigera*. Six different modules viz., Bt (750 ml / ha) – HaNPV (250 LE / ha) – Bt (750 ml / ha), Bt (750 ml / ha) – HaNPV (250 LE / ha) – endosulfan (0.06 %), endosulfan (0.06 %) – Bt (750 ml / ha) – HaNPV (250 LE / ha), NSKE (5 %) – Bt (750 ml / ha) – HaNPV (250 LE / ha), Bt (750 ml / ha) - HaNPV (250 LE / ha) – spinosad (0.01 %) and spinosad (0.01 %) – Bt (750 ml /

ha) + HaNPV (250 LE / ha) were evaluated against standard check i.e. three sprays of endosulfan and untreated control.

Both these field experiments were conducted at the field of Department of Entomology, Dr. PDKV, Akola during post rainy seasons of 2003-04 and 2004-05. Applications of treatment were initiated after attaining economic threshold level and repeated at fifteen days interval. Observations on larval count at 3, 7, 10 and 14 days after spraying were recorded. Similarly, grain yield was also recorded from individual treatment / module.

To study the seasonal incidence of pest, weekly observations on larval population of pest on ten randomly selected plants from separately sown plot were undertaken. Twenty five eggs and larvae were collected at weekly interval and were reared in the laboratory and observed daily for emergence of parasitoid.

Effect of malic acid on larval and pupal development of *H. armigera* was studied by rearing the larvae on malic acid fortified, water washed and untreated chickpea leaves till the adult emergence. The results so obtained are summarized as

6.1 Evaluatin of microbial insecticides either alone or in combination

6.1.1 Effect of various treatments on larval population of *H. armigera* 3 and 7 days after spraying

Similar results were observed in larval population due to various treatments after both sprays at both the intervals. Lowest larval population was recorded in spinosad (0.01 %) and endosulfan (0.06 %). Treatment HaNPV (250 LE / ha), Bt (550 ml / ha) and their combination HaNPV (125 LE / ha) + Bt (375 ml / ha) stood next to these and were followed by *Metarhizium anisopliae* (2.5 kg / ha) and *Beauveria bassiana* (2.5 kg / ha).

Treatment combinations viz., *Metarhizium anisopliae* (1.25 kg / ha) + HaNPV (25 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + Bt (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + HaNPV (125 LE / ha) and *Beauveria bassiana* (1.25 kg / ha) + Bt (375 ml / ha) recorded more larval population thus proved least effective.

6.1.2 Effect of various treatments on larval population of *H. armigera* ten and fourteen days after spraying

Similar results were observed in larval population due to various treatments after both sprays at both the intervals, treatments spinosad (0.01 %) and endosulfan (0.06 %) were consistently found most effective by recording least larval population. These two treatments were followed by HaNPV (250 LE / ha). *Metarhizium anisopliae* (2.5 kg / ha) and *Beauveria bassiana* (2.5 kg / ha).

Treatments Bt (750 ml / ha) and HaNPV (125 LE / ha) + Bt (375 ml / ha) recorded moderate larval population while treatment combinations viz., *Metarhizium anisopliae* (1.25 kg / ha) + HaNPV (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + Bt (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + HaNPV (125 LE / ha) and *Beauveria bassiana* (1.25 kg / ha) + Bt (375 ml / ha) was consistently less effective in reducing *H. armigera* number.

6.1.3 Effect of various treatments on grain yield of chickpea

Highest grain yield of chickpea was harvested from the plots treated with spinosad (0.01 %) and endosulfan (0.06 %) which produced statistically at par grain yield.

These two treatments were followed by HaNPV (250 LE / ha), Bt (750 ml / ha) and HaNPV (125 LE / ha) + Bt (375 ml / ha). Application of myco-insecticides such as *Metarhizium anisopliae* (2.5 kg / ha) and *Beauveria bassiana* (2.5 kg / ha) also produced better grain yield but their combinations viz., *Metarhizium anisopliae* (1.25 kg / ha) + HaNPV (125 LE / ha), *Beauveria bassiana* (1.25 kg /

ha) + HaNPV (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + Bt (375 ml / ha) and *Beauveria bassiana* (1.25 kg / ha) + Bt (375 ml / ha) gave least grain yield.

6.1.4 Incremental cost benefit ratio of various treatments

ICBR of various treatments clearly showed that endosulfan (0.06 %) was economically most viable treatment followed by HaNPV (250 LE /ha) and HaNPV (125 LE / ha) + Bt (375 ml / ha).

Next economical treatment in order were Bt (750 ml / ha), spinosad (0.01 %), *Beauveria bassiana* (2.5 kg / ha) and *Metarhizium anisopliae* (2.5 kg / ha).

However treatment combinations of myco-insecticides such as *Metarhizium anisopliae* (1.25 kg / ha) + HaNPV (125 LE / ha), *Beauveria bassiana* (1.25 kg / ha) + HaNPV (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + Bt (375 ml / ha) and *Beauveria bassiana* (1.25 kg / ha) + Bt (375 ml / ha) gave less ICBR but were economically viable over control.

6.2 Evaluation of different modules for bio intensive management of *H. armigera*

6.2.1 Effect of various modules on larval population of *H. armigera*

Module M_7 consisted of three sprays of endosulfan (0.06 %) was most effective and recorded least cumulative average population of *H. armigera*. This module did not differ from module M_5 consisted of Bt (750 ml / ha) – HaNPV (250 LE / ha) – spinosad (0.01%).

Module M_2 comprising of Bt (750 ml / ha) – HaNPV (250 LE / ha) – endosulfan (0.06 %), M_6 having spinosad (0.01 %) - Bt (750 ml / ha) – HaNPV (250 LE / ha) and M_3 with endosulfan (0.06 %) - Bt (750 ml / ha) – HaNPV (250 LE / ha) were moderately effective in reducing *H. armigera* population.

However, module M_1 consisted of Bt (750 ml / ha) - HaNPV (250 LE / ha) – Bt (750 ml / ha) and M_4 having NSKE (5 %) - Bt (750 ml / ha) – HaNPV (250 LE / ha) were less effective.

6.2.2 Effect of various modules on grain yield of chickpea

Module M_7 with three sprays of endosulfan (0.06 %) produced highest grain yield which was at par with that produced by module M_5 having Bt (750 ml / ha) – HaNPV (250 LE / ha) – spinosad (0.01 %).

These two modules were followed by module M_2 comprising Bt (750 ml / ha) – HaNPV (250 LE / ha) – endosulfan (0.06 %), M_6 having spinosad (0.01 %) – Bt (750 ml / ha) - HaNPV (250 LE / ha) and M_3 with endosulfan (0.06 %) – Bt (750 ml / ha) – HaNPV (250 LE / ha).

However, module M_1 consisted of Bt (750 ml / ha) -- HaNPV (250 LE / ha) -- Bt (750 ml / ha) and M_4 consisted of NSKE (5 %) – Bt (750 ml / ha) – HaNPV (250 LE / ha) recorded lowest grain yield.

6.2.3 Incremental cost benefit ratio of various modules

Module M_7 with three sprays of endosulfan (0.06 %) was emerged as most economically viable module followed by module M_2 comprising of Bt (750 ml / ha) – HaNPV (250 LE / ha) -- endosulfan (0.06 %)

Next economically viable module in order were M_3 endosulfan (0.06 %) -- Bt (750 ml / ha) -- HaNPV (250 LE / ha), M_4 NSKE (5 %) -- Bt (750 ml / ha) -- HaNPV (250 LE /ha), M_5 Bt (750 ml / ha) – HaNPV (250 LE / ha) – spinosad (0.0 %) and M_1 Bt (750 ml / ha) – HaNPV (250 LE / ha) – Bt (750 ml / ha).

However, module M_6 consisted of spinosad (0.01 %) -- Bt (750 ml / ha) -- HaNPV (250 LE / ha) stood last in economical ranking.

6.3 Relationship between larval population of *H. armigera*, its field parasitization and weather parameters

6.3.1 Seasonal incidence of *H. armigera*

During *rabi* 2003-04, incidence of *H. armigera* on chickpea crop was noticed one month after sowing which reached at its peak(7 larvae / 10 plants) during 49th and 50th meteorological week. It was seen to be favoured by temperature between 16.5 to 32.2 and 11.9 to 31.2 °C while humidity between 33 to 77 % and 21 to 64 % of its previous week, respectively.

During *rabi* 2004-05, peak incidence of pest (13 larvae / 10 plants) was noticed during 48th meteorological week favoured by temperature between 12.9 to 32.0 °C and relative humidity of 22 to 66 % during its previous week.

6.3.2 Parasitization of pests

No egg and pupal parasitoid was recorded from eggs and pupae of *H. armigera*. However, two larval parasitoids viz., *Compoletis chlorideae* and *Eriborous* sp was found parasitizing *H. armigera* larvae. Highest parasitization due to both these parasitoids was observed in 51st meteorological week of 2003-04 favoured by temperature of 12.6 to 31.4 °C and relative humidity between 26 to 63% whereas, during 2004-05 the highest incidence was noticed during 48th meteorological week favoured by temperature 12.9 to 32.0 °C and relative humidity 22 to 66 %.

6.3.3 Correlation studies

Significant positive correlation was observed between larval population and field parasitization. Whereas, correlation between larval population and field parasitization with weather parameters was non significant.

6.4 Effect of malic acid on larval and pupal development

Malic acid has shown non significant effect on larval and pupal development of *H. armigera* during both the years of investigations.

Finally it is concluded that microbial insecticides are effective against *H. armigera* on chickpea. Amongst various microbial insecticides HaNPV @ 250 LE / ha , Bt @ 750 ml / ha and their combination at half doses were most effective. New molecule, spinosad had proved its superiority and could be a good alternative for endosulfan. However, its high cost reduced its economical viability.

Amongst various modules tested, modules consisted of first two sprays of Bt (750 ml / ha) and HaNPV (250 LE / ha) followed by third spray of spinosad (0.01 %) or endosulfan (0.06 %) were effective again *H. armigera* which could reduce the load of chemical pesticides and environmental pollution.

Study on seasonal incidence of pest showed that the maximum incidence of pest was occurred at flowering and podding stage of crop and that in the month of December (48^{th} to 51^{st} met.week).

Compoletis chlorideae and *Eriborous* sp were the most pre-dominant larval parasitoids in chickpea under Vidharbha conditions. Its significant positive correlation with the pest population suggested that these are the important natural mortality factors of *H. armigera.*

Study on effect of malic acid on larval and pupal development indicated that malic acid has no significant effect on larval and pupal development of *H. armigera.*

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* - Original not seen

APPENDIX

APPENDIX – A

Weekly meteorological data for the post rainy seasons of 2003-04 and 2004-05 recorded at Agricultural Meteorological Observatory, Dr. PDKV, Akola

Met. Week	Dates	2003-2004					2004-2005				
		Rainfall (mm)	Temperature (°C)		R.H. (%)		Rainfall (mm)	Temperature (°C)		R.H. (%)	
			Max.	Min.	Mor.	Even.		Max.	Min.	Mor.	Even.
41	8-14 Oct.	0.0	33.3	19.6	76	38	2.7	33.0	21.4	86	45
42	15-21	0.0	33.6	18.3	87	42	0.0	32.2	14.5	70	25
43	22-28	0.0	31.9	15.8	73	30	0.0	33.0	14.6	64	19
44	29-4 Nov.	0.5	32.3	20.2	85	57	0.0	32.2	15.2	65	27
45	5-11	0.0	33.0	16.0	65	32	0.0	31.7	16.3	72	38
46	12-18	0.0	31.6	14.6	70	34	41.0	31.8	18.3	86	41
47	19-25	0.0	32.3	15.7	71	29	0.0	32.0	12.9	66	22
48	26-2 Dec.	0.0	32.2	16.5	77	33	0.0	30.5	11.7	67	23
49	3-9	0.0	31.2	11.9	64	21	0.0	29.8	10.2	62	23
50	10-16	0.0	31.4	12.6	63	26	0.0	30.1	10.3	68	22
51	17-23	0.0	28.6	10.8	72	30	0.0	30.4	9.8	66	23
52	24-31	4.9	26.8	10.3	72	36	0.0	29.8	11.9	69	32
1	1-7 Jan.	3.8	28.1	12.6	75	39	0.0	30.6	15.1	75	37
2	8-14	0.0	28.4	10.4	70	28	0.0	29.3	10.4	64	25
3	15-21	0.0	32.6	13.2	66	27	0.0	28.6	10.7	57	27

APPENDIX – B

Incremental Cost Benefit Ratio of various treatments during 2003-2004

Treatment	Insecticide ml / lit. of water	No. of sprays	Qty. of spray mixture (lit.)	Total insecticide in ml / gm	Price in Rs. / lit. or Rs. / kg	Cost of insecticide	Labour and spray pump charges	Total cost of plant protection	Yield (q / ha)	Net gain over control q / ha	Gross realization Rs / ha	Realization over control Rs. / ha	ICBR	Rank
T_1 *Metarhizium anisopliae* @2.5 kg / ha	5.00 gm	2	1000	5000	480	2400.00	396.00	2796.00	13.92	3.72	17052.00	4557.00	1 : 1.70	7
T_2 *Beauveria bassiana* @2.5 kg / ha	5.00 gm	2	1000	5000	410	2050.00	396.00	2446.00	13.72	3.52	16807.00	4312.00	1 : 1.76	6
T_3 HaNPV @250 LE / ha	0.50 ml	2	1000	500	1800	900.00	396.00	1296.00	14.51	4.31	17774.00	5279.75	1 : 4.07	2
T_4 Bt@750 ml / ha	1.50 ml	2	1000	1500	750	1125.00	396.00	1521.00	14.31	4.11	17529.75	5034.75	1 : 3.31	4
T_5 *Metarhizium anisopliae* @1.25 kg/ ha + HaNPV @125 LE / ha	2.50gm 0.25ml	2	1000	2500 250	480 1800	1200.00 450.00	396.00	2046.00	12.16	1.96	14896.00	2401.00	1 : 1.17	8
T_6 *Metarhizium anisopliae* @1.25 kg/ha + Bt@375 ml/ha	2.50gm 0.75ml	2	1000	2500 750	480 750	1200.00 562.50	396.00	2158.50	11.76	1.56	14406.00	1911.00	1 : 0.88	10
T_7 *Beauveria bassiana* @ 1.25 kg/ha+HaNPV @250 LE/ha	2.50gm 0.25 ml	2	1000	2500 250	410 1800	1025.00 450.00	396.00	1871.00	11.86	1.66	14528.50	2033.50	1 : 1.09	9
T_8 *Beauveria bassiana* @ 1.25 kg/ha+Bt@375 ml/ha	2.50gm 0.75ml	2	1000	2500 750	410 750	1025.00 562.50	396.00	1983.50	11.08	0.88	13573.00	1078.00	1 : 0.54	11
T_9 HaNPV @ 250 LE / ha + Bt @ 375 ml / ha	0.25ml 0.75ml	2	1000	250 750	1800 750	450.00 562.50	396.00	1408.50	14.02	3.82	17174.50	4679.50	1 : 3.32	3
T_{10} Endosulfan @ 0.06 %	1.71ml	2	1000	1710	314	536.94	396.00	932.94	15.88	5.68	19453.00	6958.00	1 : 7.45	1
T_{11} Spinosad @ 0.01 %	0.22ml	2	1000	220	10800	2376.00	396.00	2772.00	16.27	6.07	19930.75	7435.75	1 : 2.68	5
T_{12} Untreated control	-	-	-	-	-	-	-	-	10.20	-	12495.00	-	-	-

Note : 1) **Cost of Insecticides :**

i) *Metarhizium anisopliae* - Rs.480 / kg
ii) *Beauveria bassiana* - Rs. 410 / kg
iii) HaNPV - Rs.1800 / lit.
iv) *Bacillus thurengiensis* – Rs. 750 / lit.
v) Endosulfan - Rs. 314 / lit.
vi) Spinosad - Rs. 10800 / lit.

2) Price of Cickpea Grains – Rs.1225.00 / q.
3) Labour charges – Rs. 47 / day
4) Spray pump charges – 10 / day
5) Quantity of Water required for :
i) First spray –500 lit. ii) Second spray – 500 lit.

APPENDIX – C

Incremental Cost Benefit Ratio of various treatments during 2004-2005.

Treatment	Insecticide ml / lit. of water	No. of sprays	Qty. of spray mixture (lit.)	Total insecticide in ml / gm	Price in Rs. / lit. or Rs. / kg	Cost of insecticide	Labour and spray pump charges	Total cost of plant protection	Yield (q / ha)	Net gain over control q / ha	Gross realization Rs. / ha	Realization over control Rs. / ha	ICBR	Rank
T_1 *Metarhizium anisopliae* @2.5 kg / ha	5.00 gm	2	1000	5000	480	2400.00	396.00	2796.00	12.06	2.94	13386.60	3263.40	1 : 1.17	7
T_2 *Beauveria bassiana* @2.5 kg / ha	5.00 gm	2	1000	5000	410	2050.00	396.00	2446.00	11.76	2.64	13053.60	2930.40	1 : 1.20	6
T_3 HaNPV @250 LE / ha	0.50 ml	2	1000	500	1800	900.00	396.00	1296.00	12.94	3.82	14363.40	4240.20	1 : 3.27	2
T_4 Bt@750 ml / ha	1.50 ml	2	1000	1500	750	1125.00	396.00	1521.00	12.64	3.52	14030.40	3960.20	1 : 2.57	4
T_5 *Metarhizium anisopliae* @1.25 kg/ ha + HaNPV @125 LE / ha	2.50gm 0.25ml	2	1000	2500 250	480 1800	1200.00 450.00	396.00	2046.00	11.12	2.00	12343.20	2220.00	1 : 1.09	8
T_6 *Metarhizium anisopliae* @1.25 kg/ha + Bt@375 ml/ha	2.50gm 0.75ml	2	1000	2500 750	480 750	1200.00 562.50	396.00	2158.50	10.39	1.27	11532.90	1409.70	1 : 0.65	10
T_7 *Beauveria bassiana* @ 1.25 kg/ha+HaNPV @250 LE/ha	2.50gm 0.25 ml	2	1000	2500 250	410 1800	1025.00 450.00	396.00	1871.00	10.69	1.57	11865.90	1742.70	1 : 0.93	9
T_8 *Beauveria bassiana* @ 1.25 kg/ha+Bt@375 ml/ha	2.50gm 0.75ml	2	1000	2500 750	410 750	1025.00 562.50	396.00	1983.50	10.19	1.07	11310.90	1187.70	1 : 0.60	11
T_9 HaNPV @ 250 LE / ha + Bt @ 375 ml / ha	0.25ml 0.75ml	2	1000	250 750	1800 750	450.00 562.50	396.00	1408.50	12.55	3.43	13930.50	3807.30	1 : 2.70	3
T_{10} Endosulfan @ 0.06 %	1.71ml	2	1000	1710	314	536.94	396.00	932.94	14.41	5.29	15,995.10	5871.90	1 : 6.29	1
T_{11} Spinosad @ 0.01 %	0.22ml	2	1000	220	10800	2376.00	396.00	2772.00	14.90	5.78	16539.00	6415.80	1 : 2.31	5
T_{12} Untreated control	-	-	-	-	-	-	-	-	9.12	-	10123.20	-	-	-

Note : 1) Cost of Insecticides :

i) *Metarhizium anisopliae* - Rs.480 / kg
ii) *Beauveria bassiana* - Rs. 410 / kg
iii) HaNPV - Rs.1800 / lit.
iv) *Bacillus thurengiensis* – Rs. 750 / lit.
v) Endosulfan - Rs. 314 / lit.
vi) Spinosad - Rs. 10800 / lit.

2) Price of Cickpea Grains – Rs.1225.00 / q.
3) Labour charges -- Rs. 47 / day
4) Spray pump charges – 10 / day
5) Quantity of Water required for :
ii)First spray –500 lit. ii) Second spray - 500 lit.

APPENDIX – D

Incremental Cost Benefit Ratio of various treatments during Pooled.

Treatment	Insecticide ml / lit. of water	No. of sprays	Qty. of spray mixture (lit.)	Total insecticide in ml / gm	Price in Rs. / lit. or Rs. / kg	Cost of insecticide	Labour and spray pump charges	Total cost of plant protection	Yield (q / ha)	Net gain over control q / ha	Gross realization Rs. / ha	Realization over control Rs. / ha	ICBR	Rank
T_1 *Metarhizium anisopliae* @2.5 kg / ha	5.00 gm	2	1000	5000	480	2400.00	396.00	2796.00	12.99	3.33	15165.83	3887.78	1 : 1.39	7
T_2 *Beauveria bassiana* @2.5 kg / ha	5.00 gm	2	1000	5000	410	2050.00	396.00	2446.00	12.74	3.08	14873.95	3595.90	1 : 1.47	6
T_3 HaNPV @250 LE / ha	0.50 ml	2	1000	500	1800	900.00	396.00	1296.00	13.73	4.07	16029.78	4751.73	1 : 3.67	2
T_4 Bt@750 ml / ha	1.50 ml	2	1000	1500	750	1125.00	396.00	1521.00	13.48	3.82	15737.90	4759.85	1 : 2.93	4
T_5 *Metarhizium anisopliae* @1.25 kg/ ha + HaNPV @125 LE / ha	2.50gm 0.25ml	2	1000	2500 250	480 1800	1200.00 450.00	396.00	2046.00	11.64	1.98	13589.70	2311.65	1 : 1.13	8
T_6 *Metarhizium anisopliae* @1.25 kg/ha + Bt@375 ml/ha	2.50gm 0.75ml	2	1000	2500 750	480 750	1200.00 562.50	396.00	2158.50	11.08	1.42	12935.90	1657.85	1 : 0.77	10
T_7 *Beauveria bassiana* @ 1.25 kg/ha+HaNPV @250 LE/ha	2.50gm 0.25 ml	2	1000	2500 250	410 1800	1025.00 450.00	396.00	1871.00	11.28	1.62	13169.40	1891.35	1 : 1.01	9
T_8 *Beauveria bassiana* @ 1.25 kg/ha+Bt@375 ml/ha	2.50gm 0.75ml	2	1000	2500 750	410 750	1025.00 562.50	396.00	1983.50	10.63	0.97	12410.53	1132.48	1 : 0.57	11
T_9 HaNPV @ 250 LE / ha + Bt @ 375 ml / ha	0.25ml 0.75ml	2	1000	250 750	1800 750	450.00 562.50	396.00	1408.50	13.29	3.63	15516.08	4238.03	1 : 3.01	3
T_{10} Endosulfan @ 0.06 %	1.71ml	2	1000	1710	314	536.94	396.00	932.94	15.15	5.49	17.887.63	6409.58	1 : 6.87	1
T_{11} Spinosad @ 0.01 %	0.22ml	2	1000	220	10800	2376.00	396.00	2772.00	15.59	5.93	18201.33	6923.28	1 : 2.50	5
T_{12} Untreated control	-	-	-	-	-	-	-	-	9.66	-	11278.05	-	-	-

Note : 1) Cost of Insecticides :

i) *Metarhizium anisopliae* - Rs.480 / kg
ii) *Beauveria bassiana* - Rs. 410 / kg
iii) HaNPV - Rs.1800 / lit.
iv) *Bacillus thurengiensis* – Rs. 750 / lit.
v) Endosulfan - Rs. 314 / lit.
vi) Spinosad - Rs. 10800 / lit.

2) Price of Cickpea Grains – Rs.1225.00 / q.
3) Labour charges – Rs. 47 / day
4) Spray pump charges – 10 / day
5) Quantity of Water required for :
iii) First spray –500 lit. ii) Second spray – 500 lit.

APPENDIX – E

Incremental Cost Benefit Ratio of various modules during 2003-2004.

Module No.	Insecticide ml / lit. of water	No. of sprays	Qty. of spray mixture (Lit.)	Total insecticide in ml / gm	Price in Rs. / lit. or Rs. / kg.	Cost of insecticides Rs./ha	Labour and spray pump charges Rs./ha	Total cost of plant protection Rs./ha	Yield (q / ha)	Net gain over control q / ha	Gross realization Rs. / ha	Realization over control Rs. / ha	ICBR	Rank
Bt @ 750 ml / ha	1.50	1	500	750	750	750	594.00	2544.00	15.23	4.78	18656.75	5855.50	1 : 2.30	6
HaNPV @ 250 LE / ha	0.50	1	500	250	1800	450								
Bt @ 750 ml / ha	1.50	1	500	750	750	750								
Bt @ 750 ml / ha	1.50	1	500	750	750	750	594.00	2062.47	16.21	5.76	19857.25	7056.00	1 : 3.42	2
HaNPV @ 250 LE / ha	0.50	1	500	250	1800	450								
Endosulfan @ 0.06 %	1.71	1	500	855	314	268.47								
Endosulfan @ 0.06 %	1.71	1	500	855	314	268.47	594.00	2062.47	15.57	5.12	19073.25	6272.00	1 : 3.04	3
Bt @ 750 ml / ha	1.50	1	500	750	750	750								
HaNPV @ 250 LE / ha	0.50	1	500	250	1800	450								
NSKE @ 5 %	50.0	1	500	25000	5	125	594.00	1919.00	14.87	4.42	18215.75	5414.50	1 : 2.82	4
Bt @ 750 ml / ha	1.50	1	500	750	750	750								
HaNPV @ 250 LE / ha	0.50	1	500	250	1800	450								
Bt @ 750 ml / ha	1.50	1	500	750	750	750	594.00	2982.00	16.43	5.98	20126.75	7325.50	1 : 2.46	5
HaNPV @ 250 LE / ha	0.50	1	500	250	1800	450								
Spinosad @ 0.01 %	0.22	1	500	110	10800	1188								
Spinosad @ 0.01 %	0.22	1	500	110	10800	1188	594.00	2982.00	15.77	5.32	19318.25	6517.00	1 : 2.19	7
Bt @ 750 LE / ha	1.50	1	500	750	750	750								
HaNPV @ 250 LE / ha	0.50	1	500	250	1800	450								
Endosulfan @ 0.06 %	1.71	1	500	855	314	268.47	594.00	1399.41	16.70	6.25	20457.50	7656.25	1 : 5.47	1
Endosulfan @ 0.06 %	1.71	1	500	855	314	268.47								
Endosulfan @ 0.06 %	1.71	1	500	855	314	268.47								
Untreated control	-	-	-	-	-	-	-	-	10.45	-	12801.25	-	-	-

Note : 1) Cost of Insecticides :

i) *Bacillus thurengiensis* – Rs. 750 / lit.
ii) HaNPV - Rs.1800 / lit.
iii) NSKE - Rs. 5 / kg
iv) Endosulfan - Rs. 314 / lit.
v) Spinosad - Rs. 10800 / lit.

2) Price of Cickpea Grains – Rs.1225.00 / q.
3) Labour charges – Rs. 47 / day
4) Spray pump charges – 10 / day
5) Quantity of Water required for :i)First spray-500 lit ii) Second spray – 500 lit. iii) Third Spray – 500

APPENDIX – F

Incremental Cost Benefit Ratio of various modules during 2004-2005.

Module No.	Insecticide ml / lit. of water	No. of sprays	Qty. of spray mixture (Lit.)	Total insecticide in ml / gm	Price in Rs. / lit. or Rs. / kg.	Cost of insecticides Rs./ha	Labour and spray pump charges Rs./ha	Total cost of plant protection Rs./ha	Yield (q / ha)	Net gain over control q / ha	Gross realization Rs. / ha	Realization over control Rs. / ha	ICBR	Rank
Bt @ 750 ml / ha HaNPV @ 250 LE / ha Bt @ 750 ml / ha	1.50 0.50 1.50	1 1 1	500 500 500	750 250 750	750 1800 750	750 450 750	594.00	2544.00	13.53	4.23	15018.30	4695.30	1 : 1.85	7
Bt @ 750 ml / ha HaNPV @ 250 LE / ha Endosulfan @ 0.06 %	1.50 0.50 1.71	1 1 1	500 500 500	750 250 855	750 1800 314	750 450 268.47	594.00	2062.47	14.72	5.42	16339.20	6016.20	1 : 2.92	2
Endosulfan @ 0.06 % Bt @ 750 ml / ha HaNPV @ 250 LE / ha	1.71 1.50 0.50	1 1 1	500 500 500	855 750 250	314 750 1800	268.47 750 450	594.00	2062.47	14.11	4.81	15662.10	5339.10	1 : 2.59	3
NSKE @ 5 % Bt @ 750 ml / ha HaNPV @ 250 LE / ha	50.0 1.50 0.50	1 1 1	500 500 500	25000 750 250	5 750 1800	125 750 450	594.00	1919.00	13.13	3.83	14574.30	4251.30	1 : 2.82	4
Bt @ 750 ml / ha HaNPV @ 250 LE / ha Spinosad @ 0.01 %	1.50 0.50 0.22	1 1 1	500 500 500	750 250 110	750 1800 10800	750 450 1188	594.00	2982.00	14.82	5.52	16450.20	6127.20	1 : 2.05	5
Spinosad @ 0.01 % Bt @ 750 LE / ha HaNPV @ 250 LE / ha	0.22 1.50 0.50	1 1 1	500 500 500	110 750 250	10800 750 1800	1188 750 450	594.00	2982.00	14.29	4.99	15861.90	5538.90	1 : 2.86	6
Endosulfan @ 0.06 % Endosulfan @ 0.06 % Endosulfan @ 0.06 %	1.71 1.71 1.71	1 1 1	500 500 500	855 855 855	314 314 314	268.47 268.47 268.47	594.00	1399.41	15.21	5.91	16883.10	6560.10	1 : 4.69	1
Untreated control	-	-	-	-	-	-	-	-	9.30	-	10323.00	-	-	-

Note : 1) Cost of Insecticides :

i) *Bacillus thurengiensis* – Rs. 750 / lit.
ii) HaNPV - Rs.1800 / lit.
iii) NSKE - Rs. 5 / kg
iv) Endosulfan - Rs. 314 / lit.
v) Spinosad - Rs. 10800 / lit.

2) Price of Cickpea Grains – Rs.1225.00 / q.
3) Labour charges – Rs. 47 / day
4) Spray pump charges – 10 / day
5) Quantity of Water required for : i)First spray-500 lit ii) Second spray – 500 lit iii) Third Spray -500 lit

APPENDIX – G

Incremental Cost Benefit Ratio of various modules (Pooled).

Module No.	Insecticide ml / lit. of water	No. of sprays	Qty. of spray mixture (Lit.)	Total insecticide in ml / gm	Price in Rs. / lit. or Rs. / kg.	Cost of insecticides Rs./ha	Labour and spray pump charges Rs./ha	Total cost of plant protection Rs./ha	Yield (q / ha)	Net gain over control q / ha	Gross realization Rs. / ha	Realization over control Rs. / ha	ICBR	Rank
Bt @ 750 ml / ha HaNPV @ 250 LE / ha Bt @ 750 ml / ha	1.50 0.50 1.50	1 1 1	500 500 500	750 250 750	750 1800 750	750 450 750	594.00	2544.00	14.38	4.50	16788.65	5253.75	1 : 2.07	6
Bt @ 750 ml / ha HaNPV @ 250 LE / ha Endosulfan @ 0.06 %	1.50 0.50 1.71	1 1 1	500 500 500	750 250 855	750 1800 314	750 450 268.47	594.00	2062.47	15.47	5.59	18061.23	6526.33	1 : 3.16	2
Endosulfan @ 0.06 % Bt @ 750 ml / ha HaNPV @ 250 LE / ha	1.71 1.50 0.50	1 1 1	500 500 500	855 750 250	314 750 1800	268.47 750 450	594.00	2062.47	14.84	4.96	17325.70	5790.80	1 : 2.81	3
NSKE @ 5 % Bt @ 750 ml / ha HaNPV @ 250 LE / ha	50.0 1.50 0.50	1 1 1	500 500 500	25000 750 250	5 750 1800	125 750 450	594.00	1919.00	14.00	4.12	16345.00	4810.10	1 : 2.51	4
Bt @ 750 ml / ha HaNPV @ 250 LE / ha Spinosad @ 0.01 %	1.50 0.50 0.22	1 1 1	500 500 500	750 250 110	750 1800 10800	750 450 1188	594.00	2982.00	15.63	5.75	18284.03	6713.13	1 : 2.25	5
Spinosad @ 0.01 % Bt @ 750 LE / ha HaNPV @ 250 LE / ha	0.22 1.50 0.50	1 1 1	500 500 500	110 750 250	10800 750 1800	1188 750 450	594.00	2982.00	15.03	5.15	17547.53	6012.63	1 : 2.02	7
Endosulfan @ 0.06 % Endosulfan @ 0.06 % Endosulfan @ 0.06 %	1.71 1.71 1.71	1 1 1	500 500 500	855 855 855	314 314 314	268.47 268.47 268.47	594.00	1399.41	15.96	6.08	18633.30	7098.40	1 : 5.07	1
Untreated control	-	-	-	-	-	-	-	-	9.88	-	11534.90	-	-	-

Note : 1) Cost of Insecticides :

i) *Bacillus thurengiensis* – Rs. 750 / lit.
ii) HaNPV - Rs.1800 / lit.
iii) NSKE - Rs. 5 / kg
iv) Endosulfan - Rs. 314 / lit.
v) Spinosad - Rs. 10800 / lit.

2) Price of Cickpea Grains – Rs.1225.00 / q.
3) Labour charges – Rs. 47 / day
4) Spray pump charges – 10 / day
5) Quantity of Water required for : i)first spray-500 lit. ii) Second spray – 500 lit. iii) Third Spray – 500

VITA

VITA

Sameer Narendra Kale was borne on 8th July, 1978 at Hinganghat, District Wardha in the State of Maharashtra, India. He passed his Secondary School Certificate (S.S.C.) examination from D.R. Patil High School, Harish Colony, Akola in the year 1994 and Higher Secondary School Certificate (H.S.S.C.) examination from Jagruti Vidyalaya, Akola in the year 1996.

He obtained his B.Sc. (Agri.) degree from College of Agriculture, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola, in first division during 2000. He was admitted in the Post Graduate Institute, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola, for his post graduate studies in the subject of Agricultural Entomology during 2000. The degree of M.Sc. (Agri.) was conferred on him by Dr.PDKV, Akola with 8.60 C.G.P.A. (First Division with Distinction) in 2002.

He was again admitted to Post Graduate Institute, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during 2002-03 for Ph.D. degree course. He has keen interest in research work and has published 5 research articles and 4 popular articles.

THESIS ABSTRACT

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a. Title of the thesis	:	MICROBIAL MANAGEMENT OF *Helicoverpa armigera* (Hubner) ON CHICKPEA
b. Full name of student	:	SAMEER NARENDRA KALE
c. Name and address of Major Advisor	:	Dr. U.B. Men Associate Professor, Dept.of Entomology, Dr.PDKV, Akola
d. Degree to be awarded	:	Ph.D (Agriculture)
e. Year of award of degree	:	2006
f. Major subject	:	Agricultural Entomology
g. Total number of pages in thesis	:	150
h. Number of words in the abstract	:	775
i. Signature of the student	:	
j. Signature, name and address of forwarding authority	:	Head Deptt. of Agricultural Entomology, Dr.PDKV, Akola

HEAD
Department of Entomology
Dr. Panjabrao Deshmukh, Krishi Vidyapeeth, AKOLA (M.S.)

ABSTRACT

To evaluate the efficacy of microbial insecticides, their combinations and some bio-intensive modules against *H. armigera* in chickpea as well as to study seasonal incidence, biotic complex and effect of malic acid on larval and pupal development of *H. armigera* present investigations were undertaken at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* season of 2003-04 and 2004-05.

In order to evaluate efficacy of microbial insecticides and their combinations, a field experiment was laid out in RBD with three replications. Microbial insecticides such as *Metarhizium anisopliae* (2.5 kg / ha), *Beauveria bassiana* (2.5 kg / ha), HaNPV (250 LE / ha), Bt (750 ml / ha) and their combinations viz., *Metarhizium anisopliae* (1.25 kg / ha) + HaNPV (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + Bt (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + HaNPV (125 LE / ha), *Beauveria bassiana* (1.25 kg / ha) + Bt (375 ml / ha) and HaNPV (125 LE / ha) + Bt (375 ml / ha) were evaluated in comparison with endosulfan (0.06 %), spinosad (0.01 %) and untreated control.

Pooled results of the study indicated consistently superior performance of spinosad and endosulfan in reducing the larval population at all the intervals. These two treatments were followed by HaNPV, Bt, HaNPV + Bt, *Metarhizium anisopliae* and *Beauveria bassiana* at three and seven days after spraying. Whereas, at 10 and 14 days after spraying treatment with fungal pathogens recorded less larval population than Bt and HaNPV + Bt combinations. Treatment combinations viz., *Metarhizium anisopliae* + HaNPV, *Metarhizium anisopliae* + Bt, *Beauveria bassiana* + HaNPV and *Beauveria bassiana* + Bt were consistently found less effective.

As regards grain yield spinosad and endosulfan produced highest grain yield and were followed by HaNPV and Bt. HaNPV + Bt, *Metarhizium anisopliae*, *Beauveria bassiana*, *Metarhizium anisopliae* + HaNPV, *Beauveria* *bassiana* + HaNPV, *Metarhizium anisopliae* + Bt and *Beauveria bassiana* + Bt. Cost benefit analysis of treatments showed that endosulfan was most economical treatment followed by HaNPV, HaNPV + Bt and Bt. Spinosad though produced highest grain yield ranked fifth and was followed by *Metarhizium anisopliae*, *Beauveria bassiana*, *Metarhizium anisopliae* + HaNPV, *Beauveria bassiana* + HaNPV, *Metarhizium anisopliae* + Bt and *Beauveria bassiana* + Bt.

To evaluate various bio-intensive module another field experiment was laid out in RBD with three replications. Six bio-intensive modules viz., Bt (750 ml / ha) – HaNPV (250 LE /ha) – Bt (750 ml / ha), Bt (750 ml / ha) – HaNPV (250 LE /ha) – endosulfan (0.06 %), endosulfan (0.06 %) - Bt (750 ml / ha) – HaNPV (250 LE /ha), NSKE (5 %) - Bt (750 ml / ha) – HaNPV (250 LE /ha), Bt (750 ml / ha) -- HaNPV (250 LE /ha) – spinosad (0.01 %) and spinosad (0.01 %) - Bt (750 ml / ha) – HaNPV (250 LE /ha) were evaluated against three sprays of endosulfan (0.06 %) and untreated control.

Module with three sprays of endosulfan recorded lowest larval population and highest grain yield and was at par with module consisted of Bt – HaNPV – spinosad. Both these modules were followed by modules comprising of Bt – HaNPV – endosulfan, spinosad – Bt -- HaNPV and endosulfan - Bt – HaNPV which recorded moderate larval population and grain yield. However, module containing Bt – HaNPV – Bt and NSKE – Bt – HaNPV recorded highest larval population and lowest grain yield.

Cost benefit analysis showed that modules with three sprays of endosulfan was economically most viable recorded highest ICBR followed by module having Bt – HaNPV – endosulfan, endosulfan – Bt – HaNPV and NSKV – Bt – HaNPV. However, modules consisted of Bt – HaNPV – spinosad, Bt – HaNPV – Bt and spinosad – Bt – HaNPV recorded less ICBR.

To study the seasonal incidence of *H. armigera* on chickpea, weekly observations on larval population were taken on ten randomly selected plants from separately sown plot. Results of the study revealed that the highest incidence of pest was favoured by temperature range of 11.9 to 32.2 °C and humidity range of 21 to 64%.

Twenty five eggs and larvae were collected at weekly interval from separately sown field to study the biotic complex of the pest. Eggs was kept in hatching while larvae were reared in the laboratory till the adult emergence. The study revealed that only two larval parasitoids viz., *Compoletis chlorideae* and *Eriborous* sp were pre-dominant in chickpea ecosystem parasitized maximum up to 36 larvae of *H. armigera*.

Effect of malic acid on larval and pupal development was studied by rearing the larvae up to adult stage on malic acid enriched, water washed and untreated chickpea leaves. Observations on larval, pre-pupal and pupal period showed that malic acid has no significant effect on larval and pupal development on *H. armigera*.

bassiana + HaNPV, *Metarhizium anisopliae* + Bt and *Beauveria bassiana* + Bt. Cost benefit analysis of treatments showed that endosulfan was most economical treatment followed by HaNPV, HaNPV + Bt and Bt. Spinosad though produced highest grain yield ranked fifth and was followed by *Metarhizium anisopliae*, *Beauveria bassiana*, *Metarhizium anisopliae* + HaNPV, *Beauveria bassiana* + HaNPV, *Metarhizium anisopliae* + Bt and *Beauveria bassiana* + Bt.

To evaluate various bio-intensive modules another field experiment was laid out in RBD with three replications. Six bio-intensive modules viz., Bt (750 ml / ha) – HaNPV (250 LE /ha) – Bt (750 ml / ha), Bt (750 ml / ha) – HaNPV (250 LE /ha) – endosulfan (0.06 %), endosulfan (0.06 %) - Bt (750 ml / ha) – HaNPV (250 LE /ha), NSKE (5 %) - Bt (750 ml / ha) – HaNPV (250 LE /ha), Bt (750 ml / ha) – HaNPV (250 LE /ha) – spinosad (0.01 %) and spinosad (0.01 %) - Bt (750 ml / ha) – HaNPV (250 LE /ha) were evaluated against three sprays of endosulfan (0.06 %) and untreated control.

Module with three sprays of endosulfan recorded lowest larval population and highest grain yield and was at par with module consisted of Bt – HaNPV – spinosad. Both these modules were followed by modules comprising of Bt – HaNPV – endosulfan, spinosad – Bt – HaNPV and endosulfan - Bt – HaNPV which recorded moderate larval population and grain yield. However, module containing Bt – HaNPV – Bt and NSKE – Bt – HaNPV recorded highest larval population and lowest grain yield.

In order to evaluate efficacy of microbial insecticides and their combinations, a field experiment was laid out in RBD with three replications. Microbial insecticides such as *Metarhizium anisopliae* (2.5 kg / ha), *Beauveria bassiana* (2.5 kg / ha), HaNPV (250 LE / ha), Bt (750 ml / ha) and their combinations viz., *Metarhizium anisopliae* (1.25 kg / ha) + HaNPV (125 LE / ha), *Metarhizium anisopliae* (1.25 kg / ha) + Bt (375 ml / ha), *Beauveria bassiana* (1.25 kg / ha) + HaNPV (125 LE / ha), *Beauveria bassiana* (1.25 kg / ha) + Bt (375 ml / ha) and HaNPV (125 LE / ha) + Bt (375 ml / ha) were evaluated in comparison with endosulfan (0.06 %), spinosad (0.01 %) and untreated control.

Pooled results of the study indicated consistently superior performance of spinosad and endosulfan in reducing the larval population at all the intervals. These two treatments were followed by HaNPV, Bt, HaNPV + Bt, *Metarhizium anisopliae* and *Beauveria bassiana* at three and seven days after spraying. Whereas, at 10 and 14 days after spraying treatment with fungal pathogens recorded less larval population than Bt and HaNPV + Bt combinations. Treatment combinations viz., *Metarhizium anisopliae* + HaNPV, *Metarhizium anisopliae* + Bt, *Beauveria bassiana* + HaNPV and *Beauveria bassiana* + Bt were consistently found less effective.

As regards grain yield spinosad and endosulfan produced highest grain yield and were followed by HaNPV and Bt, HaNPV + Bt, *Metarhizium anisopliae*, *Beauveria bassiana*, *Metarhizium anisopliae* + HaNPV, *Beauveria*

THESIS ABSTRACT

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b. Full name of student	:	SAMEER NARENDRA KALE
c. Name and address of Major Advisor	:	Dr. U.B. Men Associate Professor, Dept.of Entomology, Dr.PDKV, Akola
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ABSTRACT

To evaluate the efficacy of microbial insecticides, their combinations and some bio-intensive modules against *H. armigera* in chickpea as well as to study seasonal incidence, biotic complex and effect of malic acid on larval and pupal development of *H. armigera* present investigations were undertaken at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* season of 2003-04 and 2004-05.