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SG Khorasiya
Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat, India

KL Raghvani
Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat, India

AM Bharadiya
Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat, India

JB Bhut
Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat, India

Correspondence
AM Bharadiya
Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat, India

Bio-efficacy of some bio-pesticides, insecticides alone and their combinations against *H. armigera* infesting chickpea

SG Khorasiya, KL Raghvani, AM Bharadiya and JB Bhut

Abstract
Among the bio-pesticides *Ha*NPV@ 250 LE ha^{-1} was found most effective against *H. armigera* which recorded significantly the highest per cent mortality(80.61 and 82.61%) at 50 per cent flowering and 50 per cent pod formation stage, respectively which also noticed significantly registered the highest grain yield (1264 kg ha^{-1}). *B. thuringiensis* @1.0 kg ha^{-1} was also found equally effective against *H. armigera*. In case of insecticides, chlorantraniliprole 0.006 per cent found significantly most effective which recorded the highest per cent mortality (83.59 and 85.59%) at 50 per cent flowering and 50 per cent pod formation, respectively and also recorded highest grain yield (1383 kg ha^{-1}). In combination of insecticides and bio-pesticides *Ha*NPV 125 LE ha^{-1} with chlorantraniliprole 0.003 per cent found significantly most effective. The highest ICBR *i.e.* 10.19 was observed in *Ha*NPV @ 250 LE/ha which was followed by *Ha*NPV @ 125 LE ha^{-1} + chlorantraniliprole 0.003 per cent (8.06).

Keywords: Bio-efficacy, Bio-pesticides, Insecticides, *H. armigera*, Chickpea

Introduction
Chickpea (*Cicer arielinun* l Linn.) also known as bengal gram or gram. chana, garbanzo etc., is one of the most important pulse crops of India and is considered as "King of Pulses" (Bhatt and Patel, 2001) [4]. India accounts for 68% of total global output of chickpea and incidentally it is one of the largest consumers. Chickpea is grown in about 8.68 million hectare in India with tentative production of 5.35 million tonnes. In 2010-11, the estimated production was about 8.25 MT, a record in the last 50 year. Four states *viz*, Madhya- Pradesh, Uttar- Pradesh, Maharashtra and Rajasthan together contribute about 87% of production from area. In Gujarat, area under chickpea has been reported 2.39 lakh hectares with total production of 2.73 lakh tones and productivity of 1139 kg/ha during rabi 2011-12 (DOAC, 2013) [7].

The productivity of chickpea crop has not witnessed any significant jump as compared to the cereal crops, because of several biotic and abiotic constraints. Among the many biotic factors responsible for low yield, damage due to insect pests is the major limiting factor (Bhagwat *et.al*., 1995) [3]. Chickpea crop is attacked by nearly 57 species of insect and other arthropods in India (Lal, 1992) [10]. Among them, pod borer *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is most important and accounts for about 90 to 95% of the total damage caused by all the insect pests (Sachan and Katti, 1994) [13]. This pest is popularly known as "gram pod borer", while in the U.S.A., it is called "bollworm" or "American bollworm" or "Corn worm". Synonyms of gram pod borer *Heliothis armigera* (Hubner) reported by Singh *et.al*. (1989) [15] are as *Heliothis obsoleta* Fabricius, *Helicoverpa armigera* (Hubner), *Chloridae armigera* (Hubner) and *Chloridae obsoleta* Fabricius. It has been reported 3.6-72.8 per cent pod damage in chickpea (Patnaik *et al.*, 1991) [11].

Chickpea is one of the major pulse crops in India and widely grown in Saurashtra region of Gujarat State. This crop is attacked by *H. armigera*, which causes the economic damage Due to the development of resistance toward the commonly used insecticides, this pest has created a serious threat to the agricultural industry. To overcome such problem, it is necessary to develop IPM module which helps to manage the population of *H. armigera* below ETL and conserve the bio-agent and also helps in reducing the environmental pollution. Looking to the present scenario, hence effort was made to know the role of use of bio-pesticides against gram pod borer alone and in combination with newer insecticides, definatly provides some useful

information which will help in the reducing insecticidal pollution and conserving bio-control agents.

Materials and Methods

A field experiment was carried out to ascertain the field efficacy of bio-pesticides alone and in combination with newer insecticides against *H. armigera* on chickpea. The details of the experiment are as under.

1. Title of Experiment: Bio-efficacy of bio-pesticides, insecticides alone and their combinations against *H. armigera* of chickpea
2. Location: Instructional Farm, JAU, Junagadh.
3. Crop and Variety: Gujarat Gram – 1 (GG-1)
4. Seed rate: 60-65 kg/ha
5. Fertilizers (NPK kg/ha): 20 - 40 - 0
6. Season and year: *Rabi*, 2011-12 and 2012-13
8. Experimental design: Randomized Block Design (Factorial)
9. Treatment combination: 12
10. No. of replication: 3
11. Spacing: 45 cm x 15 cm (row to row and plant to plant)
12. Plot size: Gross - 5.0 x 2.7 m, Net - 4.0 x 1.8 m
13. Date of Sowing: 15th November 2011 and 15th November 2012
14. Date of harvesting: 16th March 2012 and 12nd March 2013

A: Bio-pesticides:

1. B_0 Untreated
2. B_1 *Bacillus thuringiensis* @ 1.0 kg/ha
3. B_2 *Ha*NPV @ 250 LE/ha
4. B_3 *Beauveria bassiana* @ 2.0 kg/ha (2 x 10^8)

B: Insecticides:

1. I_0 Untreated
2. I_1 Flubendiamide 480 SC @ 0.007%
3. I_2 Chlorantraniliprole 20 SC @ 0.006%

Table 1: Treatment combinations of bio-pesticides and insecticides

Sr. No.	Treatment Combination	Treatment combination details
1	$B_0 + I_0$	Untreated control
2	$B_0 + I_1$	Untreated control + Flubendiamide 480 SC @ 0.007%
3	$B_0 + I_2$	Untreated control + Chlorantraniliprole 20 SC @ 0.006%
4	$B_1 + I_0$	*B. thuringiensis* @ 1.0 kg/ha + Untreated control
5	$B_1 + I_1$	*B. thuringiensis* @ 0.5 kg/ha + Flubendiamide 480 SC @ 0.0035%
6	$B_1 + I_2$	*B. thuringiensis* @ 0.5 kg/ha + Untreated control
7	$B_2 + I_0$	*Ha*NPV @ 250 LE/ha + Untreated control
8	$B_2 + I_1$	*Ha*NPV @ 125 LE/ha + Flubendiamide 480 SC @ 0.0035%
9	$B_2 + I_2$	*Ha*NPV @ 125 LE/ha + Chlorantraniliprole 20 SC @ 0.003%
10	$B_3 + I_0$	*B. bassiana* @ 2.0 kg/ha + Untreated control
11	$B_3 + I_1$	*B. bassiana* @ 1.0 kg/ha + Flubendiamide 480 SC @ 0.0035%
12	$B_3 + I_2$	*B. bassiana* @ 1.0 kg/ha + Chlorantraniliprole 20 SC @ 0.003%

Application of treatments

All the recommended agronomical practices were followed. Two sprays of bio-pesticides / insecticides at mentioned doses were applied, first at 50 per cent flowering stage and second at 50 per cent pod formation stage. When bio-pesticides and insecticides were used in combination then half dose of bio-pesticides and insecticides was taken. The pesticide was applied by using knapsack sprayer during evening hours. Care was taken to rinse the sprayer thoroughly before and after each spray with soap water to avoid the residue of previous treatment.

Method of recording the observations

Observations on number of larvae were recorded from 5 randomly selected plant at 1, 3 and 7 day after spray from each plot. The data recorded on larval population was converted to per cent mortality using the formula given by Henderson and Tilton, 1955 [8].

$$\text{Corrected per cent mortality (\%)} = 100 \times 1 - \left[\frac{Ta - Cb}{Tb - Ca}\right]$$

Where,
T_b = number of larvae observed before treatment,
T_a = number of larvae observed after treatment,
C_b = number of larvae observed from untreated control plot before treatment,
C_a = number of larvae observed from untreated control plot after treatment.
The data thus obtained was transformed into arcsine transformation before statistical analysis.

Yield and Economics

The grain yield obtained from each net plot was converted on hectare basis and subjected to statistical analysis. The per cent increase in yield over control was calculated by using following formula:

$$\text{Yield increase over control} = \frac{T - C}{C} \times 100$$

Where,
T = Yield of respective treatment (kg/ha)
C = Yield of control (kg/ha)
The economics of all the treatments was worked out by considering current market price of chickpea grains, cost of insecticides and labour charges. Incremental Cost benefit ratio (ICBR) was worked out to compare the economics of insecticidal treatments by using following formula.

$$\text{Incremental Cost: benefit ratio} = \frac{\text{Net realization (Rs./ha)}}{\text{Total cost of Insecticides or Bio-pesticides (Rs./ha)}} \text{ (ICBR)}$$

Results and Discussion

Bio-efficacy at 50 per cent flowering stage

Effectiveness of insecticides and bio-pesticides alone and in combination was evaluated against *H. armigera* at 50 per cent flowering stage of the crop. The per cent mortality of *H. armigera* at one, three and seven days after spray of different bio-pesticide and insecticides was calculated and the pooled results are presented in Table 2.

One day after spraying

The data on per cent mortality of *H. armigera* at 50 per cent flowering recorded at one day after spray of different bio-pesticide (Table 2) found statistically significant. *Ha*NPV @ 250 LE/ha recorded the highest mortality of *H. armigera i.e.* 33.78 per cent at one day after spray. *B. thuringiensis* @ 2.0 kg/ha (30.00%) and *B. bassiana* @ 2.0 kg/ha (27.37) recorded significantly moderately effective against *H. armigera.*

In case of insecticides, differences in per cent mortality of *H. armigera* at one day after spray were found statistically significant. Chlorantraniliprole 0.006 per cent recorded significantly the highest per cent mortality *i.e.* 46.87 per cent which was statistically at par with flubendiamide 0.007 per cent (43.85%). However, both the insecticidal treatments were found statistically equally effective over untreated control.

Data on per cent mortality of *H. armigera* regarding interaction of bio-pesticide and insecticides presented in Table 2, indicated that the difference of per cent mortality of *H. armigera* after one day of spraying were found statistically significant. The treatment combination of (B_0I_1) chlorantraniliprole 0.006 per cent alone recorded the highest per cent mortality *i.e.* 57.12 per cent. However, it was statistically at par with (B_0I_2) flubendiamide 0.007 per cent alone as it recorded 50.00 per cent mortality of *H. armigera.*

Three days after spray

Data on per cent mortality of *H. armigera* presented in Table 2 found statistically significant. The application of *Ha*NPV @ 250 LE/ha recorded highest mortality of *H. armigera i.e.* 64.01 per cent and it was found statistically at par with *B. thurengeinsis* @ 1.0 kg/ha (61.25%). whereas, the treatment of *B. bassiana* @ 2.0 kg/ha (51.88%) found moderately effective in controlling *H. armigera* after three days of spraying. While in case of insecticides, difference in per cent mortality of *H. armigera* after three days of application was found statistically significant. Chlorantraniliprole 0.006 per cent recorded the highest per cent of mortality *i.e.* 72.60 per cent. It was found statistically at par with flubendiamide 0.007 per cent (68.78%).

Investigated per cent mortality of larval population of *H. armigera* due to combination of bio-pesticide with insecticides presented in Table 2 indicated that all the treatment combinations were found significantly superior over untreated control. The treatment combination (B_0I_2) chlorantraniliprole 0.006 per cent alone was found to be the most effective which noted 87.79 per cent mortality of *H. armigera*. However, it was found at par with (B_0I_1) flubendiamide 0.007 per cent alone (84.60%). The next best treatment combination were (B_2I_2) *Ha*NPV @ 125 LE/ha + chlorantraniliprole 0.003 per cent, (B_1I_2) *B. thuringiensis* @ 0.5 kg/ha+ chlorantraniliprole 0.003 per cent, (B_1I_1) *B. thuringiensis* @ 0.5 kg/ha + flubendiamide 0.0035 per cent and (B_2I_1) *Ha*NPV @ 125 LE/ ha + flubendiamide 0.0035 per cent which noted 72.59, 68.57, 65.90 and 64.03 per cent mortality, respectively.

Seven days after spraying

The difference in per cent mortality of *H. armigera* was found statistically significant at seven days after application of bio-pesticides and insecticides (Table 2). Among the bio-pesticides *Ha*NPV @ 250 LE/ha found to be most effective treatment which registered 80.61 per cent mortality of *H. armigera* after seven days of application. However, it was found statistically at par with *B. thuregiensis* @ 1.0 kg/ha (74.96%). In case of insecticides, differences in per cent mortality of *H. armigera* after seven days of application were found significant. Chlorantraniliprole 0.006 per cent recorded the highest per cent mortality of *H. armigera i.e.* 83.59 per cent after seven days of application, which was statistically at par with flubendiamide 0.007 per cent (80.43%).

Perusal of the data on larval per cent mortality of *H. armigera* presented in Table 2 indicated that difference in per cent mortality of various treatment combinations found statistically significant. The treatment combination (B_0I_2) chlorantraniliprole 0.006 per cent alone was found to be the most effective which showed 93.92 per cent mortality of *H. armigera*. However, it was found statistically at par with (B_0I_1) flubendiamide 0.007 per cent alone (91.04%) after seven days of insecticidal spray. The next best treatment combinations were (B_2I_2) *Ha*NPV @ 125 LE/ ha + chlorantraniliprole 0.003 per cent, (B_2I_1) *Ha*NPV @ 125 LE/ ha + flubendiamide 0.0035 per cent, (B_1I_2) *B. thuringiensis* @ 0.5 kg/ha + chlorantraniliprole 0.003 per cent, (B_1I_1) *B. thuringiensis* @ 0.5 kg/ha + flubendiamide 0.0035 per cent, (B_3I_0) *Ha*NPV @ 250 LE/ha alone and (B_3I_2) *B. bassiana* @ 1.0 kg/ha + chlorantraniliprole 0.003 per cent which noted 83.49, 82.06, 78.79, 77.36, 75.97 and 75.11 per cent mortality, respectively.

Bio-efficacy at 50% pod formation stage

Effectiveness of insecticides and bio-pesticides alone and in combination was evaluated against *H. armigera* at 50 per cent pod formation stage of the crop. The per cent mortality of *H. armigera* at one, three and seven days after spray of different bio-pesticide and insecticides was calculated and the pooled results are presented in Table 3.

One day after spraying

The pooled data on per cent mortality of *H. armigera* recorded at one day after spray in various bio-pesticide and insecticides were found significant. The treatment *Ha*NPV @ 250 LE/ha recorded the highest mortality of *H. armigera i.e.* 35.72 per cent which was statistically at par with *B. thuringensis* @ 1.0 kg/ha (31.77%).

In case of insecticides, differences in per cent mortality of *H. armigera* at one day after second spray were found statistically significant. Chlorantraniliprole 20 SC 0.006 per cent recorded significantly highest per cent mortality *i.e.* 49.16 per cent after one day of spraying followed by flubendiamide 0.007 per cent (46.68%). However, both the insecticidal treatments were found statistically superior over untreated control against *H. armigera* after one day of insecticidal application.

Data on per cent mortality of *H. armigera* regarding interaction of bio-pesticide and insecticides indicated that the differences of per cent mortality of *H. armigera* after one day of spraying were found statistically significant. The treatment combination (B_0I_2) chlorantraniliprole 0.006 per cent alone was found to be the most effective which noted 57.53 per cent mortality of *H. armigera*. However, it was found at par with (B_0I_1) flubendiamide 0.007 per cent (54.89%). The next best treatment combinations were (B_2I_2) *Ha*NPV @ 125 LE/ha + chlorantraniliprole 0.003 per cent, (B_1I_2) *B. thuringiensis* @ 0.5 kg/ha + chlorantraniliprole 0.003 per cent, (B_2I_1) *Ha*NPV @ 125 LE/ ha + flubendiamide 0.0035 per cent, (B_1I_1) *B. thuringiensis* @ 0.5 kg/ha + flubendiamide 0.0035 per cent and (B_3I_2) *B. bassiana* @ 1.0 kg/ha + chlorantraniliprole 0.003 per cent which noted 49.17, 46.66, 46.65, 43.60 and 43.29 per cent mortality, respectively.

Three days after spraying

Pooled data on per cent mortality of *H. armigera* presented in Table 3 indicated that *Ha*NPV @ 250 LE/ha recorded the highest mortality of *H. armigera i.e.*71.68 per cent and it was found statistically at par with *B. thuringensis* @ 1.0 kg/ha (65.87%). In case of insecticides, both the insecticides were found statistically effective than untreated control. The treatment of chlorantraniliprole 0.006 per cent recorded the highest per cent mortality of *H. armigera* (75.61%) which was statistically at par with flubendiamide 0.007 per cent (72.85%).

Pooled data on per cent mortality of *H. armigera* in combination of bio-pesticide with insecticides presented in Table 2 indicated that all the treatment combinations were found significantly superior over untreated control. The treatment combinations (B_0I_2) chlorantraniliprole 0.006 per cent alone was found to be the most effective which noted 88.89 per cent mortality of *H. armigera*. However, it was found at par with (B_0I_1) flubendiamide 0.007 per cent (87.52%). The next best treatment combination were (B_2I_2) *Ha*NPV @ 125 LE/ha + chlorantraniliprole 0.003 per cent, (B_2I_1) *Ha*NPV @ 125 LE/ ha + flubendiamide 0.0035 per cent, (B_1I_2) *B. thuringiensis* @ 0.5 kg/ha+ chlorantraniliprole 0.003 per cent which noted 75.92, 74.06 and 72.11 per cent mortality, respectively.

Seven days of spraying

The pooled data on per cent mortality of *H. armigera* recorded at seven days after application of bio-pesticides and insecticides are presented in Table 2 indicated that *Ha*NPV @ 250 LE/ha found to be the most effective treatment which recorded the highest per cent mortality of *H. armigera i.e.*82.61 per cent and thus found the most effective bio-pesticide against *H. armigera*. However, it was found statistically at par with *B. thuringensis* @ 1.0 kg/ ha (76.49%). While in case of insecticides, both the insecticides were found statistically effective against *H. armigera* than untreated control. However, chlorantraniliprole 0.006 per cent recorded the highest per cent mortality of *H. armigera* (85.59%) which was statistically at par with flubendiamide 0.007 per cent (82.58%).

Pooled data of per cent mortality of *H. armigera* presented in Table 3 showed that difference in the treatment combination found statistically significant. The treatment combination of (B_0I_2) chlorantraniliprole 0.006 per cent alone was found to be the most effective, which showed 96.52 per cent mortality of *H. armigera*. However, it was found statistically at par with (B_0I_1) flubendiamide 0.007 per cent alone (93.57%) after seven days of insecticidal spray. The next best treatment combinations were (B_2I_2) *Ha*NPV @ 125 LE/ ha + chlorantraniliprole 0.003 per cent, (B_2I_1) *Ha*NPV @ 125 LE/ ha + flubendiamide 0.0035 per cent, (B_1I_2) *B. thuringiensis* @ 0.5 kg/ha + chlorantraniliprole 0.003 per cent, (B_3I_0) *Ha*NPV @ 250 LE/ha, (B_1I_1) *B. thuringiensis* @ 0.5 kg/ha + flubendiamide 0.0035 per cent which noted 85.26, 84.25, 80.34, 77.99 and 77.36 per cent mortality, respectively.

Critical examination of the pooled data on per cent mortality of *H. armigera* at different interval during both the spray indicated that bio-pesticide was found ineffective against *H. armigera* after one day of application. However, these bio-pesticides recorded comparatively higher per cent mortality of *H. armigera* after three and seven days of application. Among the various bio-pesticide, *Ha*NPV @ 250 LE/ha and *B. thuringiensis* @ 1.0 kg/ha were found more effective as compared to fungal based bio-pesticide *i.e. B. bassiana* @ 2.0 kg/ha. Pote and Chavan (2006) [12] reported that *Ha*NPV and Delfin when sprayed at pod formation stage were found equally effective as that of chemical spray in reducing the incidence of *H. armigera* on chickpea. Kulat *et al.* (2001) [9] reported that *Ha*NPV 500LE/ha and Dipel 8L were found effective in restricting the development of larval population of *H. armigera* on chickpea. Ahmad *et al.* (1999) [1] found that two application of *Ha*NPV either alone or *Ha*NPV followed by insecticidal spray was found effective against *H. armigera* infesting chickpea.

In case of insecticides, both the insecticidal treatments *viz*, chlorantraniliprole 0.006 per cent and flubendiamide 0.007 per cent were found equally effective against *H. armigera* even up to seven days of application. However, the treatment of chlorantraniliprole 0.006 per cent recorded the highest per cent mortality of *H. armigera* and found the most effective insecticide for the control of *H. armigera* infesting chickpea. Similar finding was reported by Deshmukh *et al.* (2010) [6] opined that flubendiamide @ 0.007 per cent gave highest mortality of the pest in chickpea. Babar *et al*., (2012) [2] reported larval mortality found highest in flubendiamide and rynaxypyr. Satpute and Barkhade (2012) [14] reorted that chlorantraniliprole 20 SC of (30 and 40 g.a.i./ha) was found effective in reducing the pod borer complex (*H. armigera, Melangromyza obtuse* and *Exelastis atmosa*) of pigeonpea. Bhowmik *et al.* (2013) [5] reported that rynaxypyr @ 60 g a.i./ha closely followed by flubendiamide at same dose was found to be the most effective as compared to indoxacarb @ 75 g a.i./ha in reducing larval population of *H. armigera*. Javaid *et al*, (2014) noticed highest mortality in coragen (85%, 90% & 92%) at 3, 5 and 7 days after treatment (DAT), respectively. Sreekanth *et al.*(2014) [16] showed that the number of *Helicoverpa* larvae per plant were lowest in plots treated with chlorantraniliprole 20 SC (0.43), flubendiamide 480 SC (0.59) and spinosad 45 SC (0.85) as against untreated control plot (4.17) with 89.7, 85.9 and 79.6 per cent larval reduction over control, respectively. Thus, the results obtained through present investigation are more or less in accordance with earlier reports.

Grain yield

Pooled data of grain yield of both year are presented in Table 4 indicated that all the bio-pesticides and insecticides gave significantly higher yield of chickpea as compared to control. Among the various bio-pesticides, *Ha*NPV @ 250 LE/ha recorded the highest grain yield of chickpea *i.e.* 1264 kg/ha which was found statistically at par with *B. thuringiensis* @ 1.0 kg/ha (1231 kg/ha). so far as the yield recorded in insecticidal treatments is concerned (Table 4) chlorantraniliprole 0.006 per cent recorded the highest yield *i.e.* 1309 kg/ha which was found statistically at par with flubendiamide 0.007 per cent (1254 kg/ha).

The difference in yield recorded in various combinations of bio-pesticide and insecticide was found statistically significant, However, treatment combination of (B_0I_2) chlorantraniliprole 0.006 per cent alone recorded the highest yield 1383 kg/ha which was statistically at par with (B_2I_2) *Ha*NPV @ 125 LE/ha + chlorantraniliprole 0.003 per cent, (B_1I_2) *B. thuringiensis* @ 0.5 kg/ha + chlorantraniliprole 0.003 per cent, (B_0I_1) flubendiamide 0.007 per cent alone, (B_2I_1) *Ha*NPV @ 125 LE/ha + chlorantraniliprole 0.003 per cent and (B_1I_1) *B. thuringiensis* @ 0.5kg/ha + chlorantraniliprole 0.003 per cent which recorded 1350, 1333, 1300, 1267 and 1250 kg/ha, respectively.

Thus, looking to the yield data recorded in various treatment of bio-pesticides, the highest grain yield was recorded in the treatment of *Ha*NPV @ 250 LE/ha which was at par with the *B. thuringiensis* @ 1.0 kg /ha. Ahmad *et al.* (1999) [1] found that two application of *Ha*NPV either alone or *Ha*NPV followed by insecticidal spray was found effective against *H. armigera* infesting chickpea which also recorded significantly higher grain yield. Sreekanth *et al.* (2014) [16] showed that the highest grain yield was recorded in chlorantraniliprole treated plots (686 kg/ha) with 127 percent increase over control, followed by flubendiamide (595 kg/ha) in chickpea. The findings of present investigations are in close agreement with earlier research workers.

Economics of the treatments

The economics of various treatments was worked out on the basis of current market price of chickpea and management cost which includes price of insecticides and labour charges and finally ICBR value for each treatment was worked out and summarized in Table 5.

It is evident from the data presented in Table 5 that the net realization of different bio-pesticidal treatment varied from 35 to 2882 Rs./ha. The treatment of *Ha*NPV @ 250 LE/ha recorded maximum net realization *i.e.* 2882 Rs./ha, followed by *B. thuringiensis* @ 1.0 kg/ha (2049 Rs./ha) and *B. bassiana* @ 2.0 kg/ha (35 Rs./ha). Among the insecticidal treatments, chlorantraniliprole 0.006 per cent registered maximum realization *i.e.* 6953 Rs./ha followed by Flubendiamide 0.007 per cent (5573 Rs./ha).

The ICBR of different treatments were worked out (Table 5). Among different biopesticidal treatment the highest ICBR *i.e.* 1:4.57 recorded in the treatment of *Ha*NPV @ 250 LE/ha followed by *B. thuringiensis* @ 1.0 kg/ha (1:0.696). In case of insecticidal treatments the highest ICBR was noticed in the treatment of chlorantraniliprole 0.006 per cent (1:2.78) followed by flubendiamide 0.007 per cent (1:1.68). The ICBR of different treatment combinations were worked out (Table 5). Among different treatment combinations the highest ICBR *i.e.* 1:10.19 was observed in (B_2I_0) *Ha*NPV @ 250 LE/ha which was followed by (B_2I_1) *Ha*NPV @ 125 LE/ha + chlorantraniliprole 0.003 per cent (1: 8.06).

Looking the results of net realization and ICBR values found in different treatments indicated that the treatment of *Ha*NPV @ 250 LE/ha was found to be most economical bio pesticides which registered maximum net realization of 2882 Rs./ha and highest ICBR *i.e.* 1:4.57. However, remaining bio-pesticidal treatments were found moderately effective. Visalakshmi *et al*. (2005) [17] evaluated the effect of various integrated pest management (IPM) components against *H. armigera* and reported that among various IPM components, *Ha*NPV was found as effective as endosulfan in reducing pod damage in chickpea and also recorded the highest cost benefit ratio (1:7.01).

Among different bio-pesticides and insecticides, chlorantraniliprole 0.006 per cent alone recorded the maximum net return *i.e.* 6953 Rs./ha which was followed by flubendiamide 0.007 per cent alone (5572Rs./ha) but the incremental cost benefit ratio of chlorantraniliprole 0.006 per cent (1:2.78) was found low as compare to *Ha*NPV @ 250 LE/ha. *i.e.* 1:4.57, which may be due to high cost of insecticides.

Babar *et al*. (2012) [2] and Sreekanth *et al.* (2014) [16] showed that the cost effectiveness of chlorantraniliprole and flubendiamide was also high and very favorable with incremental cost-benefit ratios. Thus, present finding are collaborate the results reported by the earlier workers.

Table 2: Bio-efficacy of bio-pesticides, insecticide alone and in combination against *H. armigera* at 50 per cent flowering in chickpea

Sr. No.	Treatment	1 DAS			3 DAS			7 DAS		
		2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
B_0	Untreated control	30.65 (25.99)	32.03 (28.20)	31.36 (27.09)	44.48 (49.10)	46.48 (52.58)	45.48 (50.84)	48.86 (56.71)	50.01 (58.71)	49.44 (57.71)
B_1	*B. thuringiensis*@ 1.0 kg /ha	33.35 (30.22)	33.08 (29.79)	33.21 (30.00)	50.99 (60.38)	52.02 (62.12)	51.50 (61.25)	60.73 (76.09)	59.23 (73.82)	59.98 (74.96)
B_2	*Ha*NPV@250 LE/ha	34.64 (32.31)	36.43 (35.27)	35.54 (33.78)	52.49 (62.92)	53.78 (65.09)	53.13 (64.01)	64.36 (81.28)	63.38 (79.93)	63.87 (80.61)
B_3	*B. bassiana*@ 2.0 kg/ha	31.01 (26.53)	32.09 (28.22)	31.55 (27.37)	45.15 (50.27)	47.01 (53.50)	46.08 (51.88)	57.04 (70.40)	53.88 (65.25)	55.46 (67.85)
	S.Em.±	0.92	1.18	0.75	1.67	1.54	1.14	2.21	1.68	1.39
	C.D. at 5%	2.71	3.46	2.14	4.91	4.51	3.24	6.47	4.92	3.95
I_0	Untreated control	13.07 (5.11)	15.08 (6.77)	14.07 (5.91)	31.95 (28.00)	33.42 (30.33)	32.68 (29.16)	41.96 (44.70)	41.47 (43.85)	41.71 (44.27)
I_1	Flubendiamide 480 SC @ 0.007%	41.13 (43.27)	41.80 (44.43)	41.47 (43.85)	55.38 (67.72)	56.69 (69.84)	56.03 (68.78)	64.59 (81.59)	62.90 (79.25)	63.75 (80.43)
I_2	Chlorantraniliprole 20SC@0.006%	43.04 (46.58)	43.37 (47.16)	43.20 (46.87)	57.51 (71.15)	59.36 (74.02)	58.43 (72.60)	66.69 (84.34)	65.52 (82.82)	66.10 (83.59)
	S.Em.±	0.80	1.02	0.65	1.45	1.33	0.98	1.91	1.45	1.20
	C.D. at 5%	2.35	3.00	1.85	4.25	3.91	2.81	5.61	4.26	3.42
BxI	S.Em.±	1.60	2.04	1.30	2.90	2.66	1.97	3.82	2.91	2.40
	C.D. at 5%	4.69	5.99	3.70	8.51	7.81	5.61	11.21	8.53	6.85
	C.V.%	8.55	10.59	9.66	10.41	9.26	9.83	11.47	8.90	10.29
Year				0.53			0.80			0.98
				NS			NS			NS
YxB				1.06			1.61			1.96
				NS			NS			NS
YxI				0.92			1.39			1.70
				NS			NS			NS
YxBxI				1.84			2.78			3.40
				NS			NS			NS

*Arcsin transformation. Figures in parentheses are retransformed values. DAS = Days after spray

Continue…

Interaction between bio-pesticide and insecticide

Sr. No.	Treatments combination	1 DAS			3 DAS			7 DAS		
		2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
1	$B_0 I_0$	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2	$B_0 I_1$	44.04 (48.33)	45.96 (51.67)	45.00 (50.00)	65.12 (82.30)	68.67 (86.77)	66.89 (84.60)	71.95 (90.40)	73.21 (91.65)	72.58 (91.04)
3	$B_0 I_2$	47.91 (55.07)	50.28 (59.16)	49.09 (57.12)	68.33 (86.37)	70.77 (89.15)	69.55 (87.79)	74.07 (92.47)	76.84 (94.82)	75.73 (93.92)
4	$B_1 I_0$	16.77 (8.33)	19.89 (11.57)	18.33 (9.89)	43.67 (47.67)	45.00 (50.00)	44.33 (48.84)	57.86 (71.70)	55.77 (68.36)	56.83 (70.01)
5	$B_1 I_1$	41.13 (43.27)	39.15 (39.87)	40.14 (41.56)	54.29 (65.93)	54.26 (65.88)	54.27 (65.90)	61.92 (77.85)	60.69 (76.04)	61.59 (77.36)
6	$B_1 I_2$	42.13 (45.00)	40.20 (41.66)	41.16 (43.33)	55.01 (67.12)	56.79 (70.00)	55.90 (68.57)	62.48 (78.65)	61.22 (76.82)	61.85 (77.75)
7	$B_2 I_0$	18.72 (10.30)	21.40 (13.31)	20.06 (11.76)	47.33 (54.07)	48.31 (55.77)	47.82 (54.92)	61.22 (76.82)	60.07 (75.11)	60.65 (75.97)
8	$B_2 I_1$	42.12 (44.98)	43.85 (48.00)	42.99 (46.49)	52.36 (62.54)	54.03 (65.50)	53.15 (64.03)	63.18 (79.65)	63.93 (80.69)	63.58 (80.12)
9	$B_2 I_2$	43.09 (46.66)	44.04 (48.33)	43.57 (47.50)	57.86 (71.70)	59.00 (73.48)	58.43 (72.59)	64.75 (81.80)	66.14 (83.64)	65.44 (82.72)
10	$B_3 I_0$	16.77 (8.33)	19.05 (10.65)	17.91 (9.46)	36.79 (35.87)	40.35 (41.93)	38.57 (38.87)	49.80 (58.34)	50.02 (58.72)	49.91 (58.58)
11	$B_3 I_1$	37.22 (36.60)	38.24 (38.32)	37.73 (37.46)	49.83 (58.39)	49.80 (58.34)	49.82 (58.37)	57.86 (71.70)	53.76 (65.06)	55.87 (68.52)
12	$B_3 I_2$	39.02 (39.64)	38.97 (39.54)	38.99 (39.59)	48.84 (56.67)	50.87 (60.17)	49.85 (58.43)	60.07 (75.11)	57.86 (71.70)	58.96 (73.41)

Table 3: Bio-efficacy of bio-pesticides, insecticides alone and in combination against *H. armigera* at 50 per cent pod formation in chickpea

Sr. No.	Treatment	1 DAS			3 DAS			7 DAS		
		2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
B_0	Untreated control	32.00 (28.08)	32.76 (29.28)	32.38 (28.68)	45.81 (51.42)	47.42 (54.22)	46.62 (52.82)	51.93 (61.97)	51.11 (60.59)	51.52 (61.28)
B_1	*B. thuringiensis*@ 1.0 kg /ha	34.21 (31.61)	34.41 (31.93)	34.31 (31.77)	54.64 (66.52)	53.86 (65.21)	54.25 (65.87)	60.38 (75.57)	61.62 (77.41)	61.00 (76.49)
B_2	*Ha*NPV@250 LE/ha	36.90 (36.05)	36.51 (35.39)	36.70 (35.72)	57.82 (71.63)	57.88 (71.72)	57.85 (71.68)	64.54 (81.52)	66.17 (83.67)	65.35 (82.61)
B_3	*B. bassiana*@ 2.0 kg/ha	32.35 (28.64)	33.23 (30.304)	32.79 (29.33)	48.22 (55.61)	49.33 (57.54)	48.78 (56.57)	55.85 (68.48)	56.29 (69.20)	56.07 (68.84)
	S.Em.±	1.21	0.94	0.77	1.87	1.56	1.22	1.96	1.76	1.31
	C.D. at 5%	3.55	2.77	2.19	5.47	4.59	3.47	5.73	5.16	3.75
I_0	Untreated control	15.08 (6.77)	13.97 (5.83)	14.53 (6.29)	37.29 (36.70)	35.94 (34.45)	36.61 (35.57)	41.55 (43.99)	43.32 (47.08)	42.44 (45.53)
I_1	Flubendiamide 480 SC @ 0.007%	42.63 (4.87)	43.56 (47.49)	43.09 (46.68)	57.93 (71.80)	59.27 (73.89)	58.60 (72.85)	65.63 (82.97)	65.03 (82.18)	65.33 (82.58)
I_2	Chlorantraniliprole 20SC@0.006%	43.89 (48.06)	45.15 (50.26)	44.52 (49.16)	59.66 (74.48)	61.16 (76.73)	60.41 (75.61)	67.34 (85.16)	68.04 (86.02)	67.69 (85.59)
	S.Em.±	1.05	0.82	0.66	1.62	1.35	1.05	1.69	1.52	1.14
	C.D. at 5%	3.07	2.40	1.89	4.74	3.97	3.00	4.97	4.46	3.25
BxI	S.Em.±	2.09	1.63	1.33	3.23	2.71	2.11	3.39	3.02	2.28
	C.D. at 5%	6.14	4.79	3.79	9.48	7.94	6.01	9.93	8.93	6.49
	C.V.%	10.71	8.27	9.56	10.85	9.00	9.96	10.08	8.97	9.54
Year				0.54			0.86			0.93
				NS			NS			NS
YxB				1.08			1.72			1.86
				NS			NS			NS
YxI				0.94			1.49			1.61
				NS			NS			NS
YxBxI				1.88			2.98			3.22
				NS			NS			NS

*Arcsin transformation. Figures in parentheses are retransformed values. DAS = Days after spray Continue…

Interaction between bio-pesticide and insecticide

Sr. No.	Treatments combination	1 DAS			3 DAS			7 DAS		
		2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
1	B_0 I_0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2	B_0 I_1	47.73 (54.75)	47.88 (55.02)	47.80 (54.89)	67.93 (85.88)	70.69 (89.07)	69.31 (87.52)	76.84 (94.82)	73.79 (92.21)	75.31 (93.57)
3	B_0 I_2	48.26 (55.68)	50.40 (59.37)	49.33 (57.53)	69.50 (87.74)	71.57 (90.00)	70.53 (88.89)	78.94 (96.32)	79.55 (96.71)	79.24 (96.52)
4	B_1 I_0	19.03 (10.63)	18.03 (9.58)	18.53 (10.10)	50.79 (60.04)	49.82 (58.38)	50.31 (59.21)	56.58 (69.67)	59.00 (73.48)	57.79 (71.59)
5	B_1 I_1	40.53 (42.22)	42.12 (44.98)	41.32 (43.60)	54.89 (66.91)	53.76 (65.06)	54.32 (65.99)	61.12 (76.67)	61.92 (77.85)	61.52 (77.26)
6	B_1 I_2	43.08 (46.65)	43.08 (46.65)	43.08 (46.65)	58.26 (72.32)	57.98 (71.89)	58.12 (72.11)	63.43 (80.00)	63.93 (80.69)	63.68 (80.34)
7	B_2 I_0	23.58 (16.00)	21.43 (13.35)	22.50 (14.65)	54.33 (65.99)	52.78 (63.40)	53.55 (64.70)	61.56 (77.31)	62.48 (78.65)	62.02 (77.99)
8	B_2 I_1	43.08 (46.65)	43.09 (46.66)	43.08 (46.66)	59.05 (73.56)	59.71 (74.56)	59.38 (74.06)	65.83 (83.24)	67.40 (85.24)	66.62 (84.25)
9	B_2 I_2	44.04 (48.33)	45.00 (50.00)	44.52 (49.17)	60.07 (75.11)	61.14 (76.71)	60.61 (75.92)	66.23 (83.76)	68.62 (86.71)	67.43 (85.26)
10	B_3 I_0	17.71 (9.25)	16.43 (8.00)	17.07 (8.62)	44.03 (48.31)	41.15 (43.31)	42.59 (45.81)	48.06 (55.33)	51.81 (61.77)	49.94 (58.57)
11	B_3 I_1	39.18 (39.91)	41.15 (43.31)	40.17 (41.61)	49.83 (58.39)	52.91 (63.63)	51.37 (61.03)	58.73 (73.05)	57.00 (70.33)	57.86 (71.70)
12	B_3 I_2	40.17 (41.61)	42.12 (44.98)	41.14 (43.29)	50.79 (60.04)	53.94 (65.35)	52.36 (62.71)	60.75 (76.13)	60.07 (75.11)	60.41 (75.62)

Table 4: Grain yield and per cent increase in yield over control in chickpea

Trat. No.	Treatments	Grain yield (kg/ha)			Per cent increase in yield over control (%)
		2011-12	2012-13	Pooled	
B_0	Untreated control	1144	1153	1149	
B_1	*B. thuringiensis*@ 1.0 kg /ha	1228	1233	1231	7.13
B_2	*Ha*NPV@250 LE/ha	1261	1267	1264	10.04
B_3	*B. bassiana*@ 2.0 kg/ha	1145	1156	1150	0.12
	S.Em.±	33.57	32.38	23.32	
	C.D. at 5%	98.47	94.97	66.47	
I_0	Untreated control	1012	1050	1031	
I_1	Flubendiamide 480 SC 0.007%	1254	1254	1254	21.62
I_2	Chlorantraniliprole 20 SC 0.006%	1317	1302	1309	26.97
	S.Em.±	29.08	28.04	20.20	
	C.D. at 5%	85.28	82.25	57.57	
BxI	S.Em.±	58.15	56.08	40.40	
	C.D. at 5%	170.56	164.49	115.13	
	C.V.%	8.43	8.08	8.26	
Year	S.Em.±			16.49	
	C.D. at 5%			NS	
YxB	S.Em.±			32.98	
	C.D. at 5%			NS	
YxI	S.Em.±			28.56	
	C.D. at 5%			NS	
YxBxI	S.Em.±			57.13	
	C.D. at 5%			NS	

Interaction between bio-pesticide and insecticide

Sr. No.	Treatments Combination	Grain yield (kg/ha)		
		2011-12	2012-13	Pooled
1	B_0 I_0	750.00	817	783
2	B_0 I_1	1300	1267	1283
3	B_0 I_2	1383	1375	1379
4	B_1 I_0	1100	1133	1117
5	B_1 I_1	1250	1267	1258
6	B_1 I_2	1333	1300	1317
7	B_2 I_0	1166	1183	1175
8	B_2 I_1	1266	1283	1275
9	B_2 I_2	1350	1333	1341
10	B_3 I_0	1033	1067	1050
11	B_3 I_1	1200	1200	1200
12	B_3 I_2	1200	1200	1200

Table 5: Economics of biopesticidal and insecticidal treatments for the control of *H. armigera* infesting chickpea

Treat. No.	Treatments	No. of spray	Total quantity of insecticides (Lit. or kg. /ha.)	Price of insecticides (Rs./ lit. or kg.)	Cost of insecticides (Rs./ha)	Labour charges (Rs./ha.)	Cost of treatments (Rs./ha.)	Yield (kg/ha)	Gross realization (Rs./ha.)	Net realization (Rs./ha.)	ICBR
B_0	Untreated control	-	-	-	-	-	-	1149	28715	-	-
B_1	*B. thuringiensis* @ 1 kg/ha	2	2	1320	2640	300	2940	1231	30764	2049	1:0.70
B_2	HaNPV @ 250 LE/ha	2	500 LE	165	330	300	630	1264	31597	2882	1:4.57
B_3	*B. bassiana* @ 2 kg/ha	2	4	150	600	300	900	1150	28750	35	1:0.04
I_0	Untreated control	-	-	-	-	-	-	1031	25781	-	-
I_1	Flubendiamide 480 SC @ 0.007%	2	0.2	15000	3000	300	3300	1254	31354	5573	1:1.69
I_2	Chlorantraniliprole 20 SC 0.006%	2	0.2	11000	2200	300	2500	1309	32734	6954	1:2.78

Labour charges Rs. 150 Rs/ day
Current market price of chickpea = Rs. 25/kg

Interaction of bio-pesticides and insecticides

Treat. combination	No. of spray	Total quantity of insecticides (Lit. or kg. /ha.)	Price of insecticides (Rs./ lit. or kg.)	Cost of insecticides (Rs./ha)	Labour charges (Rs./ha.)	Cost of treatments (Rs./ha.)	Yield (kg/ha)	Gross realization (Rs./ha.)	Net realization (Rs./ha.)	ICBR
$B_0 I_0$	-	-	-	-	-	-	784	19583	-	-
$B_0 I_1$	2	0.2	15000	3000	300	3300	1283	32083	12500	1:3.78
$B_0 I_2$	2	0.2	11000	2200	300	2500	1379	34479	14896	1:5.95
$B_1 I_0$	2	2	1320	2640	300	2940	1117	27916	8333	1:2.83
$B_1 I_1$	2	1+0.1	2820	2820	300	3120	1258	31458	11875	1:3.80
$B_1 I_2$	2	1+0.1	2420	2420	300	2720	1317	32916	13333	1:4.90
$B_2 I_0$	2	500LE	330	660	300	960	1175	29375	9792	1:10.19
$B_2 I_1$	2	250+0.1	330+15000	1830	300	2130	1275	31875	12292	1:5.77
$B_2 I_2$	2	250+0.1	330+11000	1430	300	1730	1342	33542	13959	1:8.06
$B_3 I_0$	2	4	220	880	300	1180	1050	26250	6667	1:5.64
$B_3 I_1$	2	2+0.1	220+15000	3880	300	4180	1200	30000	10417	1:2.49
$B_3 I_2$	2	2+0.1	220+11000	3080	300	3380	1200	30000	10417	1:3.08

Conclusion

Based on the present study results, it can be concluded that the treatment of *Ha*NPV @ 250 LE/ha was found to be most economical bio pesticides, which registered maximum net realization of 2882 Rs./ha and highest ICBR *i.e.* 1:4.57. Among the insecticides, chlorantraniliprole 0.006 per cent alone proved best to reduce the incidence of H. armigera and in considering the different treatment combinations *Ha*NPV @ 125 LE/ha + chlorantraniliprole 0.003 per cent was found most effective in reducing the incidence of *H. armigera* and obtained higher grain yield.

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