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Bioefficacy and economics of some newer insecticides and bio-pesticides against *Helicoverpa Armigera* (Hub.) on chickpea (*Cicer Arietinum* L.) crop

Lomash Kumar, RS Bisht, Hem Singh, Ajay Kumar, Neha Pandey and Mohit Kumar

Abstract
Bioefficacy of four newer insecticides (Buprofezin 5.65%+Deltamethrin 0.72% EC, Indoxacarb15.8% EC, Flubendiamide 480 SC and Methomyl 40% SP), one conventional insecticide (Quinolphos 25% EC), four biopesticides (*Metarhizium anisopliae*, *Beauveria bassiana*, *Ha*NPV and EPN (*Heterorhabditis indica*) were evaluated against chickpea pod borer, *Helicoverpa armigera* in chickpea crop. All the treatments were found significantly effective in reducing the infestation of pod borer and increasing the yield compared with control. Application of flubendiamide @ 121.98 ml/ha was the most effective treatment in reducing the pod borer infestation and percent pod damage at all observational interval resulting highest grain yield 1833.33 kg/ha and 1802.77 kg/ha and maximum net profit Rs. 12436.62 and 12031.84/ha during 2009-10 and 2010-11, respectively and it was followed by methomyl @ 1.0 kg/ha. Among biopesticides, *Ha*NPV @ 500 LE was found more effective with highest net profit. The maximum cost benefit ratio (1: 7.09 and 1: 6.13) during 2009-10 and 2010-11, respectively was also obtained in the treatment of *Beauveria bassiana*.

Keywords: Bioefficacy, Newer Insecticides, *Helicoverpa armigera*, Chickpea

Introduction
In India, chickpea crop is mainly known for protein source, grown in tropical, subtropical and temperate regions. India ranks first among the chickpea growing nations in terms of production and cultivated area. In India, chickpea occupies 7.1 million hectares with a production of 5.75 million tonnes accounting for 30.9% and 39.9% of total pulse area and production respectively. The main chickpea producing areas are Central India *viz.*, Madhya Pradesh, Rajasthan, and Maharashtra and the upper basin Ganga and Yamuna, *viz.*, Uttar Pradesh, Punjab, Haryana, and Bihar (Handbook of Agriculture, 2006).

Of the various ecological factors, responsible for low yield of chickpea in India, the insect pests are most important. Reed *et al.*, (1987) listed 54 species of insect pests on chickpea of these the gram pod borer, *Helicoverpa armigera* (Hub), a pest of national importance in India, is one of the limiting factor in the successful cultivation of chickpea (Sharma *et al.*, 2006). Pod borer larvae feed on both foliage and pods of chickpea, yield losses are mainly due to pod damage (Lal, 1996). In India, this pest has been reported to cause 32-100% damage to pods, while yield losses has been estimated to the extent of 4.2 to 77% (Ujagir and Khare, 1987 and Singh *et al.*, 1990). According to Sharma, (1978) a single larva of *Helicoverpa armigera* can damage up to 25-30 pods of chickpea in its life time.

In spite of having certain inherent limitations, in most of the cases several insecticides is being used for the effective control of this pest, of these synthetic pyrethroids have been considered to be most potent. Hence, there is an immense need to study some newer insecticides which are eco-friendly and have greater effect on the population of the *H. armigera* and safest to the bio-agents in field conditions.

Materials and Methods
The field experiments were conducted during *Rabi* seasons of 2009-10 and 2010-11 in Randomized Block Design (RBD) having three replications and ten treatments with 5.0×3.0 m^2 plot size for evaluation of selected newer insecticides and bio-pesticides against *H. armigera* at Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, District U.S. Nagar, Uttarakhand, India. Agronomical practices recommended for the region were followed to raise the crop. There were ten treatments comprised of four newer insecticides (Buprofezin 5.65%+Deltamethrin 0.72% EC, Indoxacarb15.8% EC,

Flubendiamide 480 SC and Methomyl 40% SP), one conventional insecticides (Quinolphos 25% EC), four biopesticides (*Metarhizium anisopliae*, *Beauveria bassiana*, *Ha*NPV and EPN (*Heterorhabditis indica*) and one untreated control (Table -1). Each treatment was applied twice during the crop season after reaching pest population at economic threshold level while in untreated control plot nothing was sprayed.

Observations on infestation of pod borer as larvae, adults, live eggs per m^2 and damaged pods with circular holes per plant were recorded on ten randomly selected plants from three central rows one day before and 3, 7, 10 and 15 days after each insecticide application. The grain yield of all the plots was recorded at the time of harvest. From the yield and cost of treatments incurred in the application, the cost benefit ratio was worked out in order to find out an effective and economically viable treatment for the control of *H. armigera* in chickpea. Statistical analysis was done as suggested by Panse and Sukhatme (1967).

Results and Discussion

Bioefficacy of different insecticides and biopesticides against *H. armigera* following first application (2009-10)

The results revealed that all the treatments were significantly effective in reducing the infestation of pod borer and thus increasing the yield significantly as compared to control. The initial pod borer infestation recorded as larval population in different treatments varied from 1.73 to 2.40 larvae/10 plants which were statistically found non-significant. (Table-1)

Data recorded 3 days after pesticidal application, the minimum pod borer infestation (0.28 larvae/plot) was recorded in the plots treated with flubendiamide @ 121.98 ml/ha followed by methomyl @ 1.0kg/ha (0.44 larvae/10 plants), indoxacarb @ 500 ml/ha (0.53 larvae/10 plants), buprofezin+deltamethrin @ 500 ml/ha (0.57 larvae/ 10 plants), quinolphos @ 500 ml/ha (0.64 larvae/ 10 plants), HaNPV @ 500 LE/ ha (0.64 larvae/10 plants), *Beauveria bassiana* @ 1.0 kg/ha (0.74 larvae/10 plants), EPN (*Heterorhabditis indica*) @ 5.0 x 10^9 IJs/ha (0.77 larvae/10 plants) and *Metarhizium anisopliae* @ 1.0 kg/ha (0.79 larvae/10 plants), in comparison to control experiment which recorded maximum larval population of 1.88 larvae/10 plants.

Similar trend was recorded 7 days after spraying i.e. flubendiamide proved to be the best treatment (0.47 larvae/10 plants) and it was found significantly superior to rest of the treatments. In other treatments pod borer infestation ranged from 0.59 to 0.96 larvae per ten plants. The maximum damage was recorded in control plot with 2.18 mean larval population per ten plants.

After 10 days of pesticidal application, flubendiamide @ 121.98 ml/ha was again found most effective with lowest mean population of 0.65 larvae/10 plants which was significantly superior over rest of the treatments. The next most effective treatment was Methomyl followed by indoxacarb, buprofezin+deltamethrin, quinalphos, *Ha*NPV, *Beauveria bassiana*, *Metarhizium anisopliae* and EPN (*Heterorhabditis indica*) ranged from 0.87 to 1.06 mean larval population per ten plants in comparison, the larval population in control plot was to the extent of 2.98 larvae/10 plants.

Observations recorded on 15 days after the application revealed that flubendiamide maintained its effectiveness in reducing the pod borer infestation (1.17 larvae/10 plants). It was significantly superior to rest of the treatments. Methomyl was the next effective treatment followed by indoxacarb. Treatment *Metarhizium anisopliae* was recorded least effective with 2.03 mean larval population per 10 plants. The highest infestation 3.79 mean larval population per ten plants was recorded in control treatment.

Bioefficacy of different insecticides and biopesticides against *H. armigera* following second application (2009-10)

The second insecticidal spray was applied at 90 days after sowing. Similar trend of efficacy of insecticides as in first application on reduction of larval population was recorded (Table-1). After 3 days of the insecticidal application, all the treatments were found significantly superior than the control. The minimum mean larval population (0.27 larvae/10 plants) was recorded with flubendiamide followed by methomyl (0.35 larvae/10 plant) and the efficacy was better than all other treatments. The next in order of effectiveness of treatments were indoxacarb, buprofezin+deltamethrin, quinalphos, *Ha*NPV, *Beauveria bassiana*, EPN (*Heterorhabditis indica*) and *Metarhizium anisopliae* where mean larval population ranged from 0.40 to 0.68 larvae/10 plant. Maximum mean larval population of 4.22 larvae/10 plants was recorded in control plot.

When the larval population was recorded on the 7 days after insecticidal application, flubendiamide again proved most effective and was found statistically at par with methomyl. EPN (*Heterorhabditis indica*) though was found least effective (mean larval population 0.95 larvae/10 plants) but it was better than the untreated control.

Data taken after ten days of second application revealed that all treatments were effective and significantly superior over untreated control. Most effective treatment was flubendiamide with larval population of 0.58 larvae/10 plants followed by methomyl (0.68 larvae/10 plants) which were found statistically at par with each other. The next in order of effectiveness of treatments were indoxacarb, buprofezin + deltamethrin, quinolphos, HaNPV, *B. bassiana*, *M. anisopliae* in which larval population varied from 0.74 to 1.01 larvae/10 plant. EPN (*Heterorhabditis indica*) proved to be least effective with larval population of 1.05/10 plants. However, maximum larval population of 5.57 larvae/10 plants was recorded in control.

The observations recorded after 15 days of second application showed that all the treatments maintained their efficacy and significance over control. Flubendiamide gave the best performance and recorded minimum number of larvae (0.84 larvae/ 10 plants) as compared to other treatments. The next effective treatment was methomyl which recorded a larval population of 0.92 larvae/10 plants followed by indoxacarb, buprofezin + deltamethrin, quinolphos, *B. bassiana*, *M. anisopliae* and EPN (*Heterorhabditis indica*). The maximum larval population of 5.94 larvae/10 plants was recorded in control plot.

Table 1: Bio-efficacy of different insecticides and biopesticides against the larvae of chickpea pod borer (*H. armigera*) after first and second application (2009-10)

Treatment No.	Name of insecticide/biopesticide	Dose/ha	Mean larval population/10 plant during 1st spray					Mean larval population/10 plant during 2nd spray			
			Before spray	3 DAS**	7 DAS	10 DAS	15 DAS	3 DAS**	7 DAS	10 DAS	15 DAS
T_1	*Metarhizium anisopliae* 2×10^8 CFU/gram	1.0 kg	2.40 (1.84)*	0.79 (1.34)	0.93 (1.39)	1.06 (1.44)	2.03 (1.74)	0.68 (1.29)*	0.93 (1.39)	1.01 (1.42)	1.17 (1.47)
T_2	*Beauveria bassiana* 2×10^8 CFU/gram	1.0 kg	2.27 (1.80)	0.74 (1.32)	0.86 (1.36)	0.97 (1.40)	1.74 (1.65)	0.60 (1.26)	0.87 (1.36)	0.94 (1.39)	1.13 (1.45)
T_3	Buprofezin5.65 %+ Deltamethrin0.72% EC	500 ml	2.03 (1.74)	0.57 (1.25)	0.77 (1.33)	0.93 (1.39)	1.49 (1.57)	0.43 (1.19)	0.73 (1.31)	0.78 (1.33)	1.02 (1.42)
T_4	Quinolphos 25% EC	500 ml	2.03 (1.74)	0.64 (1.28)	0.79 (1.34)	0.95 (1.40)	1.59 (1.61)	0.49 (1.22)	0.78 (1.33)	0.83 (1.35)	1.07 (1.43)
T_5	Indoxacarb15.8% EC	500 ml	1.73 (1.65)	0.53 (1.24)	0.67 (1.29)	0.91 (1.38)	1.41 (1.55)	0.40 (1.18)	0.68 (1.29)	0.74 (1.32)	0.99 (1.41)
T_6	Ha NPV 2×10^9 POB's/ml	500 LE	2.00 (1.73)	0.64 (1.28)	0.83 (1.35)	0.97 (1.40)	1.69 (1.64)	0.54 (1.24)	0.83 (1.35)	0.87 (1.37)	1.07 (1.43)
T_7	Flubendiamide 480 SC	121.98 ml	2.20 (1.79)	0.28 (1.13)	0.47 (1.21)	0.65 (1.28)	1.17 (1.47)	0.27 (1.12)	0.46 (1.21)	0.58 (1.25)	0.84 (1.35)
T_8	EPN (*Heterorhabditis indica*)	5.0×10^9 IJ	2.03 (1.74)	0.77 (1.33)	0.96 (1.40)	1.06 (1.43)	1.99 (1.73)	0.64 (1.28)	0.95 (1.39)	1.05 (1.43)	1.32 (1.52)
T_9	Methomyl 40% SP	1.0 kg	2.33 (1.82)	0.44 (1.19	0.59 (1.26)	0.87 (1.37)	1.29 (1.51)	0.35 (1.16)	0.57 (1.25)	0.68 (1.29)	0.92 (1.38)
T_{10}	CONTROL	-	2.03 (1.74)	1.88 (1.69)	2.18 (1.78)	2.98 (1.99)	3.79 (2.19)	4.22 (2.28)	4.65 (2.37)	5.57 (2.56)	5.94 (2.63)
	SEm±		0.40	0.017	0.013	0.027	0.013	0.013	0.017	0.013	0.011
	CD (P = 0.05)		NS	0.051	0.040	0.082	0.040	0.040	0.051	0.040	0.033

* Figures in parentheses are square root transformed values, **DAS = Days after spray

Bioefficacy of different insecticides and biopesticides against *H. armigera* following first application (2010-11)

During the second year all the treatments were repeated in the same manner as in the first year of the chickpea crop. The results revealed that all the treatments were significantly effective in reducing the population of pod borer and thus significant increase in yield as compared to control. The initial larval population was in range of 2.27 to 2.83 larvae/10 plant before the spray and did not differ significantly from each other (Table-2).

After 3 days of spraying, the minimum mean larval population of 0.21 larvae/10 plants was recorded in the plots treated with flubendiamide and therefore, appeared to be most promising in reducing the population of *H. armigera*. Methomyl was observed as the next promising treatment which recorded a population of 0.27 larvae/10 plants. Nevertheless, both the treatments were found statistically at par with each other. The treatment with indoxacarb appeared next in order which registered a population of 0.37 larvae/10 plants followed by buprofezin+deltamethrin (0.43 larvae/10 plants), quinolphos (0.49 larvae/10 plants), *Ha*NPV (0.53 larvae/10 plants), *B. bassiana* (0.58 larvae/10 plants), *M. anisopliae* (0.63 larvae/10 plants). EPN (*H. Indica*) @ 5.0 x 10^9 IJs/ha on the contrary which recorded a larval population of 0.69 larvae/10 plants appeared to be least effective in reducing the larval population. However, the highest population of 1.47 larvae/10 plants was recorded in the control plot.

Similar trend was recorded 7 days after spraying as flubendiamide proved to be the best treatment (0.13 larvae/10 plants) and it was significantly superior to rest of treatments except methomyl (0.26 larvae/10 plants). In other treatments pod borer mean larval population ranged from 0.36 to 0.76 larvae/10 plants as compared to 2.36 larvae/10 plants in control plot.

After 10 days of application, all the treatments were again found significantly superior to control. Flubendiamide showed lowest population of 0.41 larvae/10 plants and therefore appeared to be most effective followed by methomyl, indoxacarb, buprofezin + deltamethrin, quinolphos, *Ha*NPV, *B. bassiana*, EPN (*H. indica)* and *M. anisopliae* where pod borer larval population was 0.56, 0.67, 0.78, 0.84, 0.93 0.97, 0.95 and 1.01 larvae/10 plants, respectively as compared to control (mean larval population 2.09 larvae/10 plants).

Observations recorded 15 days after the application of different treatment it was revealed that flubendiamide maintained its effectiveness in reducing the larval population (0.94 larvae/10 plant). It was significantly superior to rest of the treatments. Methomyl was the next effective treatment followed by indoxacarb. Treatment EPN (*H. Indica*) appeared to be least effective (1.62 larvae/10 plants). The highest population of 3.78 larvae/10 plants was recorded in control plot.

Bioefficacy of different insecticides and biopesticides against *H. armigera* following second application (2010-11)

The second pesticide spray was applied at 110 days after sowing and data are presented in Table-2. A more or less similar trend of efficacy of various treatments against pod borer population was recorded as it was in first application.

After 3 days of the pesticide application, all the treatments were found significantly superior than the control. The minimum mean number of 0.26 larvae/10 plants was recorded with flubendiamide followed by methomyl (0.31 larvae/10 plants). The next in order of effectiveness were indoxacarb, buprofezin+deltamethrin, quinolphos, *Ha*NPV, *B. bassiana*, *M. anisopliae* and EPN (*H. indica)* where the mean larval population ranged from 0.35 to 0.63 larvae/10 plants. Maximum mean larval population of 3.86 larvae/10 plants was recorded in control plot.

The observations recorded at 7 days of second application revealed that flubendiamide again found significantly superior over rest of the treatments. The second most effective treatment was methomyl where as the least effective treatment was EPN, *H. indica* with mean larval population 0.67 larvae/10 plants but it was better than untreated control in controlling pod borer population.

After 10 days of spray, flubendiamide again proved most effective (mean larval population of 0.57 larvae/10 plants) and it was statistically at par with methomyl followed by indoxacarb, buprofezin+deltamethrin, quinolphos, *Ha*NPV, *B. bassiana* and *M. anisopliae* with 0.66, 0.73, 0.79, 0.86, 0.93, 1.03 larvae/10 plants. The EPN (*H. indica*) on the other hand was found least effective where the mean number of larvae/10 plants was 1.08. However, it was better than untreated control.

The observations recorded after 15 days of the insecticidal application shows the efficacy of all the treatments decreased as compared to the data obtained 10 days after application. Flubendiamide maintained its effectiveness and gave the best performance of 0.89 larvae/10 plants followed by methomyl, indoxacarb, buprofezin+deltamethrin, quinolphos, *Ha*NPV, *B. bassiana* and *M. anisopliae* ranged mean larval population from 0.96 to 1.39 larvae/10 plants. The EPN (*H. indica*) was proved least effective but significantly superior over untreated control.

It is evident from the overall data obtained above that all the treatments in the present studies were effective in controlling chickpea pod borer population at different intervals after the first and second spray in comparison to untreated control in both the years. The most effective treatment was flubendiamide @ 121.98 ml/ha followed by methomyl @ 1.0 kg/ha and indoxacarb @ 500 ml/ha. The effectiveness of flubendiamide, methomyl and indoxacarb against *H. armigera* as reported in our findings is supported by various workers (Biradar *et al*., 2001; M.H. Tatagar *et al*., 2009;) who reported the effectiveness of these pesticides in the following descending order: Flubendiamide > Methomyl >Indoxacarb. Kumar *et al*., (2004) also reported that flubendiamide 480 SC @ 48 g a.i./ha was found to be superior in recording less larval populations of pod borers, followed by indoxacarb 14.5 SC @ 75 g a.i./ha.

Among the biopesticides Kulkarni *et al*., (2005) reported that *Ha*NPV recorded the lowest mean larval population of (1.43 larvae/10 plants) followed by *N. rileyi* (1.56 larvae/10 plants) and *M. anisopliae* (1.89 larvae/10 plants).

Table 2: Bio-efficacy of different insecticides and biopesticides against the larvae of chickpea pod borer (*H. armigera*) after first and second application (2010-11)

Treatment No.	Name of insecticide/biopesticide	Dose/ha	Mean larval population/10 plant during 1st spray					Mean larval population/10 plant during 2nd spray			
			Before spray	3 DAS**	7 DAS	10 DAS	15 DAS	3 DAS**	7 DAS	10 DAS	15 DAS
T$_1$	*Metarhizium anisopliae* 2×10^8 CFU/gram	1.0 kg	2.27 (1.80)*	0.63 (1.28)	0.73 (1.31)	1.01 (1.42)	1.52 (1.59)	0.61 (1.27)*	0.64 (1.28)	1.03 (1.42)	1.39 (1.54)
T$_2$	*Beauveria bassiana* 2×10^8 CFU/gram	1.0 kg	2.50 (1.87)	0.58 (1.25)	0.65 (1.28)	0.97 (1.40)	1.49 (1.57)	0.58 (1.25)	0.59 (1.26)	0.93 (1.38)	1.37 (1.53)
T$_3$	Buprofezin 5.65 %+ Deltamethrin 0.72% EC	500 ml	2.66 (1.91)	0.43 (1.19)	0.43 (1.19)	0.78 (1.33)	1.19 (1.48)	0.41 (1.18)	0.43 (1.19)	0.73 (1.31)	1.12 (1.45)
T$_4$	Quinolphos 25% EC	500 ml	2.63 (1.90)	0.49 (1.22)	0.51 (1.23)	0.84 (1.35)	1.24 (1.49)	0.45 (1.20)	0.45 (1.20)	0.79 (1.33)	1.18 (1.48)
T$_5$	Indoxacarb15.8% EC	500 ml	2.83 (1.95)	0.37 (1.17)	0.36 (1.16)	0.67 (1.29)	1.09 (1.44)	0.35 (1.16)	0.34 (1.16)	0.66 (1.28)	1.03 (1.42)
T$_6$	Ha NPV 2×10^9 POB's/ml	500 LE	2.63 (1.90)	0.53 (1.23)	0.57 (1.25)	0.93 (1.38)	1.46 (1.56)	0.52 (1.23)	0.50 (1.23)	0.86 (1.36)	1.28 (1.51)
T$_7$	Flubendiamide 480 SC	121.98 ml	2.57 (1.88)	0.21 (1.10)	0.13 (1.06)	0.41 (1.18)	0.94 (1.39)	0.26 (1.12)	0.22 (1.10)	0.47 (1.21)	0.89 (1.37)
T$_8$	EPN (*Heterorhabditis indica*)	5.0×10^9 IJ	2.56 (1.88)	0.69 (1.29)	0.76 (1.32)	0.95 (1.39)	1.62 (1.61)	0.63 (1.28)	0.67 (1.29)	1.08 (1.44)	1.45 (1.57)
T$_9$	Methomyl 40% SP	1.0 kg	2.37 (1.83)	0.27 (1.12)	0.26 (1.12)	0.56 (1.24)	1.02 (1.42)	0.31 (1.14)	0.32 (1.14)	0.57 (1.25)	0.96 (1.39)
T$_{10}$	CONTROL	-	2.37 (1.83)	1.47 (1.57)	2.36 (1.83)	3.40 (2.09)	3.78 (2.18)	3.86 (2.20)	4.16 (2.27)	4.57 (2.36)	4.58 (2.36)
	SEm±		0.35	0.010	0.021	0.016	0.010	0.010	0.013	0.013	0.007
	CD (P = 0.05)		NS	0.031	0.064	0.049	0.031	0.031	0.040	0.040	0.021

*Figures in parentheses are square root transformed values, **DAS = Days after spray

Effect of some newer insecticides and Biopesticides on the yield

Considering the data collected on the effect of some newer insecticides and biopesticides on the crop yield of chickpea are presented in Table-3. A perusal of data revealed that all the treatments were found significantly different from each other in percent pod damage during both the years. Flubendiamide resulted in least percent pod damage of 2.22% and 2.06% during the crop seasons, 2009-10 and 2010-11, respectively which were statistically at par with methomyl which resulted 2.64% and 2.19% pod damage and indoxacarb which caused 3.05 % and 2.43% pod damage during 2009-10 and 2010-11, respectively. The treatment buprofezin+deltamethrin resulted 4.01% and 3.13% pod damage during the first and the 2nd year respectively followed by quinolphos, *Ha*NPV, *B. bassiana* and *M. anisopliae* during the crop seasons 2009-10 and 2010-11, respectively. The highest pod damage of 15.18% and 13.05% in the first and second year respectively was recorded with EPN, *H. indica* but it was less than the control plot i.e. 19.17% and 18.76%, respectively.

Similar trend was recorded in yield of the crop in both the years, 2009-10 and 2010-11. Flubendiamide proved to be the best treatment with 1833.33 and 1802.77 kg/ha grain yield during the crop seasons 2009-10 and 2010-11, respectively and were found significantly superior to rest of the treatments. The next superior treatment was methomyl (1777.77 and 1730.55 kg/ha yield in the first and second years respectively) followed by indoxacarb (1744.45 and 1700.00 kg/ha), buprofezin+deltamethrin (1733.33 and 1653.33 kg/ha), quinolphos (1666.67 and 1583.34 kg/ha), *Ha*NPV (1655.55 and 1629.88 kg/ha), *B. bassiana* (1633.32 and 1594.44 kg/ha), *M. anisopliae* (1511.11 and 1567.34 kg/ha) and EPN, *H. indica* (1444.43 and 1411.09 kg/ha). The lowest grain yield was obtained from the untreated control plot with 1333.32 and 1346.66 kg/ha grain yield during the crop seasons 2009-10 and 2010-11, respectively.

Thus, flubendiamide was again appeared to be superior with 500.01 and 456.11 kg/ha more grain yield during the first and second year respectively as compared to control treatments. The next promising treatment was methomyl which resulted 444.45 kg/ha (2009-10) and 383.89 kg/ha (2010-11) more yield than control followed by indoxacarb, buprofezin+deltamethrin, quinolphos, *Ha*NPV, *B. bassiana* and *M. anisopliae*. However, the lowest yields of 111.11 kg/ha (2009-10) and 64.43 kg/ha (2010-11) was recorded in plots treated with EPN, *H. indica*. On the basis of increase in grain yield over control, flubendiamide 480 SC, therefore appeared to be the most effective insecticide among all the treatments followed by methomyl 40% SP in reducing the incidence of *H. armigera*.

Kumar *et al*., (2004) also reported the treatment of flubendiamide 480 SC @ 48 g a.i./ha as the superior insecticide in chickpea followed by flubendiamide 480 SC @ 36 g a.i./ha, indoxacarb, chlorpyriphos, quinalphos. More recently Tatagar *et al*., (2009) reported flubendiamide 20 WG @ 60 g a.i. /ha as the most promising insecticides to give highest yield with lowest pod damage against *H. armigera* larvae. Considering the efficacy of biopesticides Rachna and Kaushik (2006) evaluated the efficacy of *Ha*NPV (500 LE/ha), against *H. armigera* larvae infesting chickpea cv. C-235 and recorded the highest grain yield. Likewise, in another experiment conducted by Kulkarni *et al*., (2005) recorded the highest grain yield with *Ha*NPV followed by *M. anisopliae*, however they recorded lowest pod damage of 18.06% with *M. anisopliae* followed by *Ha*NPV (20.07%).

Table 3: Effect of some newer insecticides and biopesticides on the yield of chickpea crop at CRC, Pantnagar.

Treatment No.	Name of insecticide/biopesticide	Dose/ha	Mean Pod damage (%)		Yield (Kg/ha)		Yield Increase over control (Kg/ha)	
			2009-10	2010-11	2009-10	2010-11	2009-2010	2010-2011
T_1	*Metarhizium anisopliae* 2×10^8 CFU/gram	1.0 kg	14.23 (3.90)*	9.26 (3.17)	1511.11	1567.34	177.79	220.68
T_2	*Beauveria bassiana* 2×10^8 CFU/gram	1.0 kg	9.71 (3.27)	7.02 (2.83)	1633.32	1594.44	300.00	247.78
T_3	Buprofezin5.65 %+ Deltamethrin0.72% EC	500 ml	4.01 (2.24)	3.13 (2.02)	1733.33	1653.33	400.01	306.67
T_4	Quinolphos 25% EC	500 ml	4.39 (2.38)	3.72 (2.17)	1666.67	1583.34	333.35	236.68
T_5	Indoxacarb15.8% EC	500 ml	3.05 (2.01)	2.43 (1.84)	1744.45	1700.00	411.13	353.34
T_6	Ha NPV 2×10^9 POB's/ml	500 LE	7.52 (2.92)	5.67 (2.55)	1655.55	1629.88	322.23	283.22
T_7	Flubendiamide 480 SC	121.98 ml	2.22 (1.79)	2.06 (1.74)	1833.33	1802.77	500.01	456.11
T_8	EPN (*Heterorhabditis indica*)	5.0×10^9 IJ	15.18 (4.02)	13.05 (3.75)	1444.43	1411.09	111.11	64.43
T_9	Methomyl 40% SP	1.0 kg	2.64 (1.89)	2.19 (1.76)	1777.77	1730.55	444.45	383.89
T_{10}	CONTROL	-	19.17 (4.47)	18.76 (4.42)	1333.32	1346.66	-	-
	SEm±		0.12	0.17	7.93	6.55	-	-
	CD (P = 0.05)		0.37	0.49	23.57	19.46	-	-

*Figures in parentheses represent square root transformed values

Economics of Treatments

Evaluating the cost of chemicals required for spray in one hectare of land as shown in Table-4 is clear that the application cost of treatment *Beauveria bassiana* and *Metarhizium anisopliae* is lowest (Rs. 1112/ha) followed by *Ha*NPV (Rs. 1362.00/ha), EPN (Rs.1412/ha), buprofezin+deltamethrin (Rs. 1662.00/ha), methomyl (Rs. 1712/ha), Quinolphos (Rs. 1862/ha) and indoxacarb (Rs. 2362.00 /ha). The highest cost of treatment was recorded in flubendiamide (Rs. 2563.68/ha) during both the year, 2009-10 and 2010-11, respectively.

The results revealed that the highest net profit (Rs. 12436.62/ha) was obtained from the plots sprayed with flubendiamide followed by methomyl, buprofezin+deltamethrin, indoxacarb, *Ha*NPV, quinolphos, *Beauveria bassiana* and *Metarhizium anisopliae* with net profit Rs. 11621.50, 10338.30, 9971.90, 8304.90, 8138.50, 7888.00 and 4221.70, respectively. The lowest net profit (Rs. 1921.30/ha) was found in EPN (*Heterorhabditis indica*) in the year 2009-10.

Similar trend of net profit was also obtained during the year 2010-11 where flubendiamide had the highest net profit (Rs. 12031.84/ha). The lowest net profit (Rs. 649.76/ha) was found in EPN (*Heterorhabditis indica*).

By working out cost benefit ratio from the Table-4 it is evident that *Beauveria bassiana* ranked first indicating the maximum return Rs. 7.09 per rupee invested followed by methomyl, buprofezin+deltamethrin, *Ha*NPV, flubendiamide, quinolphos, indoxacarb, *Metarhizium anisopliae* and EPN with 1: 6.78, 1: 6.22, 1: 6.09, 1: 4.85, 1: 4.37, 1: 4.22, 3.79 and 1: 1.36 C:B ratio, respectively in the year 2009-10. Whereas in the year 2010-11 methomyl ranked first indicating the maximum return Rs. 6.17 per rupee invested followed by *Beauveria bassiana*, *Ha*NPV, *Metarhizium anisopliae*, buprofezin+deltamethrin, flubendiamide, indoxacarb, quinolphos and EPN with 1: 6.13, 1: 5.65, 1: 5.35, 1: 4.90, 1: 4.69, 1: 3.78, 3.06 and 1: 1.46 Cost:Benefit ratio, respectively. Earlier, these findings were confirmed by the work of

Shekharappa (2009) who reported that *B. bassiana* has the highest cost benefit ratio (1:6.50) followed by *Ha*NPV (1: 5.20). On the contrary, Tatagar *et al*., (2009) who reported that flubendiamide 20 WG recorded the highest cost benefit ratio 1: 5.12 followed by indoxacarb 14.5 SC (1:4.13).

Table 4: Economics of different insecticides and biopesticides against the larvae of chickpea pod borer, *H. armigera*.

Treatment No.	Name of insecticide/biopesticide	Dose/ha	Value of Increased Yield (Rs./ha)		Cost of Treatment (Rs./ha)		Net Profit (Rs./ha)		Cost Benefit Ratio	
			2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	*Metarhizium anisopliae* 2×10^8 CFU/gram	1.0 kg	5333.70	7061.76	1112	1112	4221.7	5949.76	1:3.79	1:5.35
T_2	*Beauveria bassiana* 2×10^8 CFU/gram	1.0 kg	9000.00	7928.96	1112	1112	7888	6816.96	1:7.09	1:6.13
T_3	Buprofezin5.65 %+ Deltamethrin0.72% EC	500 ml	12000.30	9813.44	1662	1662	10338.3	8151.44	1:6.22	1:4.90
T_4	Quinolphos 25% EC	500 ml	10000.50	7573.76	1862	1862	8138.5	5711.76	1:4.37	1:3.06
T_5	Indoxacarb15.8% EC	500 ml	12333.90	11306.88	2362	2362	9971.9	8944.88	1:4.22	1:3.78
T_6	Ha NPV 2×10^9 POB's/ml	500 LE	9666.90	9063.04	1362	1362	8304.9	7701.04	1:6.09	1:5.65
T_7	Flubendiamide 480 SC	121.98 ml	15000.30	14595.52	2563.68	2563.68	12436.62	12031.84	1:4.85	1:4.69
T_8	EPN (*Heterorhabditis indica*)	5.0×10^9 IJ	3333.30	2061.76	1412	1412	1921.3	649.76	1:1.36	1:1.46
T_9	Methomyl 40% SP	1.0 kg	13333.50	12284.48	1712	1712	11621.5	10572.48	1:6.78	1:6.17
T_{10}	control	-								

- Labour charge= Rs. 128/day
- Rental value of Sprayer=Rs. 100/day
- Sale Price of Yield= Rs. 3000/Quintal and Rs. 3200/Quintal, during 2009-10 and 2010-11, respectively.

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