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Impact of certain bio-pesticides on larval mortality of *Helicoverpa armigera* Hubner (Noctuidae: Lepidoptera) in chickpea

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Abstract
Impact of certain bio-pesticides and insecticide on larval mortality of *Helicoverpa armigera* were evaluated under chickpea field conditions during 2010-11 and 2011-12. In all experiments, observations were undertaken on larval mortality of the pest after 1st, 3rd, 5th, 7th, and 14th days of pesticide application. Thereafter, it was concluded that after 3rd to 14th days, all treatments were found superior over the untreated control (0.0%). Under independent and interactive studies, data received after 14th days of treatments revealed that *Btk* (1.25 kg), *Ha*NPV (350 LE), *Ha*NPV (125 LE) + *Btk* (0.5 kg), *Btk* (0.5 kg) + Quinalphos (0.02%) were observed with the highest mean larval mortality as 93.33%. *Btk* (1.25 kg) proved its highest efficacy with similar potency (93.33%) in both the years. Whereas, Azadirachtin (0.05%) was registered with the lowest mean larval mortality as 33.33%.

Keywords: Field evaluation, bio-pesticides, larval mortality, *Helicoverpa armigera,* chickpea

1. Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important winter pulse crop of India, cultivated in 9.01 million hectare with an annual production of 7.58 million tonnes with productivity of 841kg/ha [1]. It has an important place in the diet of Indian people because comparatively it gives more protein, vitamins and minerals than any other food grains [2]. Production of chickpea in our country is low, one of the major reason is the losses caused by several pests and diseases, both in field and in storage.

It is attacked by a number of insect pests and among them, the pod borer (*Helicoverpa armigera,* Noctuidae: Lepidoptera) is the most serious insect pest in the most of the chickpea growing areas of the country [3]. The attack of this pest starts from vegetative stage and continue up to the crop maturity [4]. In chickpea about 30-40% pods were found to be damaged by the pod borer resulting in the yield loss of 400 Kg/ha, whereas under favourable weather conditions the damage to pods could increase up to 90-95% [5].

Several attempts have been made towards chemical control of the pest using synthetic pyrethroids and other chemical compounds against *H. armigera*. Insecticides are generally preferred for quick action and control, but owing to their continuous, indiscriminate and excessive use, many complex problems have come up, such as development of insecticidal resistance to the pest [6, 7]. During the last three decades attempts have been made to use safer pesticides including Azadirachtin and microbial pesticides as treatment combinations. Among microbial pesticides; virus, bacteria and fungus hold some good promises. Nuclear polyhedrosis virus, *Bacillus thuringiensis*, *Metarrhizium anisopliae* and *Beauveria bassiana* are the best known among them [8, 9, 10]. The relative specificity, potential activity, environmental safety and immunity to insecticides have made microbial pesticides a favoured component of IPM strategies, and considerable efforts have been made to develop the most promising agents, *Bacillus thuringiensis* and *Helicoverpa armigera* nuclear polyhedrosis virus (*Ha*NPV) into commercially viable products [11].

Perusal of literature reveals that very little research works have been done in this region (Bihar, INDIA) regarding management of *H. armigera* through bio-pesticides. Therefore, in order to design a superior pest management model for the crop in this region, the present research study was undertaken to know the impact of certain bio-pesticides such as *Btk*, *B. bassiana*, *Ha*NPV, the botanical pesticide (Azadirachtin) and a synthetic insecticidal formulation (Quinalphos) against 2nd instar larvae of *H. armigera* under chickpea field conditions.

2. Material and Methods

The laboratory study was conducted at the Entomological lab of Bihar Agricultural University (Sabour, Bhagalpur, India) during winter 2010-11 and field trials were undertaken at Chadmari village (District-Patna, India) during winter 2010-11 and 2011-12.

2.1 Insecticides used

Active ingredients and the respective formulated products used in this study were *Ha*NPV (Biovirus-H™, PIB count-$1x10^9$/ml; Biotech International Ltd., India), *Btk* (Biolep™, Potency-50000 IU/mg; Biotech International Ltd., India), *B. bassiana* (Daman™, CFU-$1x10^9$/gm; International Panacea Ltd., India), Azadirachtin (Neemarin™, 1500ppm; International Panacea Ltd., India), and Quinalphos (Vazra™, 25EC; Cheminova India Ltd.).

2.2 Preparation of insecticidal formulations

Studies regarding effectiveness of bio-pesticides against 2nd larval instar of *H. armigera* were made by using the available commercial formulations. The viable spore count in the commercial formulation of *Btk* was around 90-102 billion spores/gm, $1X10^9$ PIB/ml for *Ha*NPV and $1X10^9$ spores/gm for *B.b.*. From stock solution of *B.b.*, dilutions were made in range from $1.0X10^6$ to $1.0X10^7$spores/ml. The required concentrations of Quinalphos, Azadirachtin were prepared from stock solution. For preparing various concentrations, the required amount of *Btk* and *B.b.* was weighed on a digital electronic balance; and *Ha*NPV, Azadirachtin, and Quinalphos were measured with the help of pipette (of 0.1 ml capacity); and were dissolved in tap water containing 0.2% Teepol and thereafter homogenous mixture was prepared by stirring the solution with a glass rod. The normal tap water along with 0.2% Teepol was used as the control.

The following formula was used to prepare different concentrations of insecticides as suggested by Singh [12].

$$\text{Amount of pesticide} = \frac{\text{Conc.of spray (\%) required X Total spray volume required}}{\text{Strength of commercial formulation (\%)}}$$

2.3 Conduction of field experiments

The chickpea variety (KPG-59, *Uday*) was sown on 2nd November 2010 and 7th November 2011 following the recommended agronomical practices of Bihar Agricultural University (Sabour, India). The plot size was 4X4m for every treatment and the path of 1.0m width was maintained around each plot. Trials were conducted in Randomized Block Designs in 3 replications in 2 sets during both the years. In the 1st set of experiment, bio-pesticides and insecticide were tested singly with high, standard and low doses as per Table-1.

While in 2nd set of experiments the interactive effects of bio-pesticides and insecticide were evaluated in treatment combinations. In such experiments, half of the standard doses were applied either as sole treatments or in treatments combinations as per Table-2.

In all sets of experiments, 2nd instar larval population were counted as per linear meter row. Insecticides were applied by the hand atomizer. Due care was taken to check the drift from one plot to another by using a curtain cloth between the plots.

Statistical analysis

The data on larval mortality of *H. armigera* were recorded at 1st, 3rd, 5th, 7th, and 14th days after treatments and subjected to statistical analyses. The data were subjected to statistical analysis after tabulation in to transformed values. The population data of larvae were transformed to $\sqrt{X+0.5}$, while data in percentages were transformed to their angular values. The data so obtained were analysed by using the analysis of variance techniques. The significance among different treatment means was judged by critical difference (C.D.) at 5% level of significance for comparison among the treatments, for which the marginal means of each treatment was considered. The following formula was used for various estimations.

(1) Standard error of mean = S.Em ± = $\sqrt{E.ms/r}$

(2) Critical difference (C.D.) = SEm X √ 2 x t 0.05

3. Results

3.1 Independent effect during 2010-11

The data recorded after 1st day of treatment revealed that the mean % larval mortality was the highest (63.33%) with Quinalphos-0.06% followed by Quinalphos-0.04%, Quinalphos-0.02%, Azadirachtin-0.15%, Azadirachtin-0.10%, and Azadirachtin-0.05% with 56.67%, 46.67%, 20.0%, 16.67%, and 03.33% of larval reduction respectively. While treatments with *Btk* (0.75 kg, 1.0 kg, 1.25 kg), *B.b.* (1.5 kg, 2.5 kg, 3.5 kg) and *Ha*NPV (150 LE, 250 LE, 350 LE) had no larval mortality. (Table-3 and Fig.1).

After 3rd to 14th day, all the treatments were superior over the control (0.0%). After 3rd day, the mean larval mortality was the highest (70.0%) in Quinalphos-0.06% followed by Quinalphos-0.04%, Quinalphos-0.02%, and *Btk*-1.25 kg with larval reduction of 66.67%, 56.67%, and 32.33%. Other treatments had 30.0% to 10.0% of mean larval reduction.

After 5th day, the larval mortality was the highest as 76.67% in case of Quinalphos-0.06% and *Btk*-1.25 kg, followed by Quinalphos-0.04% and *Btk*-1.0 kg with mean larval reduction of 73.33%. Other treatments had 70.0% to 30.0% of mean larval mortality.

After 7th day, the larval mortality was the highest (90.0%) in case of *Btk*-1.25 kg followed by *Btk*-1.0 kg, *Ha*NPV-350 LE and *B.b.*-3.5 kg with mean larval reduction of 86.67%. Rest of the treatments had 83.33% to 43.33% of mean larval reduction.

After 14th day, the larval mortality was the highest (93.33%) in case of *Btk*-1.25 kg and *Ha*NPV-350 LE, followed by *Btk*-1.0 kg and *B.b.*-2.5 kg with mean larval reduction of 90.0%. Rest of the treatments had 86.67% to 46.67% of mean larval reduction.

After 14th day of application, the efficacies of all the treatment in decreasing order were as *Btk*-1.25 kg (93.33%) = *Ha*NPV-350 LE (93.33%) < *Btk*-1.0 kg (90.0%) = *B.b.*-3.5 kg (90.0%) < *B.b.*-2.5 kg (86.67%) = *Ha*NPV-250 LE (86.67%) < Quinalphos-0.06% (80.0%) < Quinalphos-0.04% (76.67%) < *Btk*-0.75 kg (66.67%) < Azadirachtin-0.15% (63.33%) < *Ha*NPV-150 LE (60.0%) = Quinalphos-0.02% (60.0%) < *B.b.*-1.5 kg (56.67%) = Azadirachtin-0.10% (56.67%) < Azadirachtin-0.05% (46.67%).

3.2 Independent effect during 2011-12

The data recorded after 1st day of treatment revealed that the mean % larval mortality was the highest (46.67%) with Quinalphos-0.06% followed by Quinalphos-0.04%, and Quinalphos-0.02% with mean larval reduction of 33.33% and 20.0% respectively. Other effective treatments were Azadirachtin-0.15%, Azadirachtin-0.10% and Azadirachtin-0.05% with mean larval reduction of 16.67%, 13.33% and 06.67% respectively. While treatments with *Btk* (0.75 kg, 1.0 kg, 1.25 kg), *B.b.* (1.5 kg, 2.5 kg, 3.5 kg) and *Ha*NPV (150 LE, 250 LE, 350 LE) had no mortality. (Table-4 and Fig. 2).

After 3rd to 14th day, all the treatments were superior over the control (0.0%). After 3rd day, the mean larval mortality was the highest (63.33%) in Quinalphos-0.06%, followed by Quinalphos-0.04%, Quinalphos-0.02% and Azadirachtin-0.15% with mean larval reduction of 53.33%, 30.0% and 30.0% respectively. Rest of the treatments had 26.67% to 06.67% of mean larval reduction.

After 5th day, the larval mortality was the highest (76.67%) in case of Quinalphos-0.06% followed by *Btk*-1.25 kg and Quinalphos-0.04% with mean larval reduction of 70.0% and 66.67% respectively. Other treatments had 63.33% to 26.67% of mean larval reduction.

After 7th day, the larval mortality was the highest (83.33%) in case of Quinalphos-0.06% and *Btk*-1.25 kg followed by *Ha*NPV-350 LE, Quinalphos-0.04% and *Btk*-1.0 kg with mean larval reduction of 80.0%, 76.67% and 76.67% respectively. Rest of the treatments had 73.33% to 33.33% of mean larval reduction.

After 14th day, the larval mortality was the highest (93.3%) in case of *Btk*-1.25 kg, followed by *Ha*NPV-350 LE and *Btk*-1.0 kg with mean larval reduction of 90.0% and 86.67% respectively. Other treatments had 83.33% to 33.33% of mean larval reduction.

After 14th day of application, the efficacies of all the treatment in decreasing order were as *Btk*-1.25 kg (93.33%) < *Ha*NPV-350 LE (90.0%) < *Btk*-1.0 kg (86.67%) < *Ha*NPV-250 LE (83.33%) = Quinalphos-0.06% (83.33%) < *B.b.*-3.5 kg (80.0%) < Quinalphos-0.04% (76.67%) < *B.b.*-2.5 kg (70.0%) < *Btk*-0.75 kg (60.0%) < *Ha*NPV-150 LE (53.33%) = Quinalphos-0.02% (53.33%) = Azadirachtin-0.15% (53.33%) < *B.b.*-1.5 kg (46.67%) = Azadirachtin-0.10% (46.67%) < Azadirachtin-0.05% (33.33%).

3.3 Interactive effect during 2010-11

The data recorded after 1st day of treatment revealed that the mean % larval mortality was the highest (43.33%) with ½ Quinalphos + ½ Azadirachtin, followed by ½ Quinalphos (sole) and ½ *Btk* + ½ Quinalphos as 36.67 and 33.33% mean larval reduction. Rest of effective treatments had 30.0% to 10.0% of mean larval reduction. While treatments with ½ *Ha*NPV + ½ *Btk*, ½ *Ha*NPV + ½ *B.b*., ½ *Ha*NPV-sole, ½ *Btk* + ½ *B.b*., ½ *Btk*-sole, and ½ *B.b*.-sole had no effect on mean % larval reduction (Table-5 and Fig. 3).

After 3rd to 14th day, all the treatments were superior over the control (0.0%). After 3rd day, the larval mortality was the highest (60.0%) in case of ½ *Ha*NPV + ½ Quinalphos, ½ *Btk* + ½ Quinalphos and ½ Quinalphos + ½ Azadirachtin. Rest of the treatments had 53.33% to 20.0% of mean larval reduction.

After 5th day, the larval mortality was the highest (83.33%) in case of ½ *Ha*NPV + ½ Quinalphos, followed by ½ *Btk* + ½ Quinalphos (73.83%). Rest of the treatments had 66.67% to 36.67% of mean larval reduction.

After 7th day, the larval mortality was the highest (93.33%) in case of ½ *Btk* + ½ Quinalphos followed by ½ *Ha*NPV + ½ *Btk* and ½ *Ha*NPV + ½ Quinalphos as 90.0%. Rest of the treatments had 86.67% to 36.67% of mean larval reduction.

After 14th day, the larval mortality was the highest (93.33%) in case of ½ *Btk* + ½ Quinalphos and ½ *Ha*NPV + ½ *Btk* treatments. Rest of the treatments had 90.0% to 36.67% of mean larval reduction.

After 14th days of application, the efficacies of all the treatment in decreasing order were as ½ *Ha*NPV + ½ *Btk* (93.33%) = ½ *Btk* + ½ Quinalphos (93.33%) < ½ *Ha*NPV + ½ Quinalphos (90.0%) < ½ *Ha*NPV-sole (86.67%) = ½ *Btk* + ½ *B.b.* (86.67%) = ½ *Btk* + ½ Azadirachtin (86.67%) = ½ *B.b.* + ½ Quinalphos (86.67%) < ½ *Ha*NPV + ½ *B.b.* (83.33%) < ½ *Ha*NPV + ½ Azadirachtin (80.0%) < ½ Quinalphos + ½ NSKE (73.33%) < ½ Quinalphos + ½ Azadirachtin (70.0%) < ½ *B.b.* + ½ Azadirachtin (56.67%) < ½ *Btk*-sole (53.33%) < ½ Quinalphos-sole (50.0%) < ½ *B.b.*-sole (46.67%) < ½ Azadirachtin-sole (36.67%).

3.4 Interactive effect during 2011-12

The data recorded after 1st day of treatment revealed that the mean % larval mortality was the highest (40.0%) in case of ½ Quinalphos + ½ Azadirachtin and ½ Quinalphos (sole) followed by ½ *Btk* + ½ Quinalphos (36.67%). Rest of effective treatments had 33.33% to 13.33% of mean larval reduction. While treatments with ½ *Ha*NPV + ½ *Btk*, ½ *Ha*NPV + ½ *B.b*., ½ *Ha*NPV-sole, ½ *Btk* + ½ *B.b*., ½ *Btk*-sole, and ½ *B.b*.-sole had no effect on mean larval mortality (Table-6 and Fig. 4).

After 3rd to 14th day, all the treatments were superior over the control (0.0%). After 3rd day, the larval mortality was the highest (66.67%) in case of ½ *Ha*NPV + ½ Quinalphos, ½ *Btk* + ½ Quinalphos, and ½ Quinalphos + ½ Azadiractin. Rest of the treatments had 56.67% to 20.0% of mean larval reduction.

After 5th day, the mean larval mortality was the highest (86.67%) in case of ½ *Ha*NPV + ½ Quinalphos followed by ½ *Btk* + ½ Quinalphos (80.0%). Rest of the treatments had 70.0% to 43.33% of mean larval reduction.

After 7th day, the mean larval mortality was the highest (86.67%) in case of ½ *Ha*NPV + ½ Quinalphos, and ½ *Ha*NPV + ½ *Btk* followed by ½ *Btk* + ½ Quinalphos and ½ *B.b.* + ½ Quinalphos as 83.33%. Rest of the treatments had 80.0% to 46.67% of mean larval reduction.

The data recorded after 14th day of treatment revealed that the mean larval mortality was the highest (90.0%) in case of ½ *Ha*NPV + ½ *Btk* followed by ½ *Ha*NPV + ½ Quinalphos, ½ *Btk* + ½ *B.b.*, ½ *Btk* + ½ Quinalphos and ½ *B.b.* + ½ Quinalphos as 86.67%. Rest of the treatments had 80.0% to 46.67% of mean larval reduction.

After 14th days of application, the efficacies of all the treatment in decreasing order were as ½ *Ha*NPV + ½ *Btk* (90.0%) < ½ *Ha*NPV + ½ Quinalphos (86.67%) = ½ *Btk* + ½ *B.b.* (86.67%) = ½ *Btk* + ½ Quinalphos (86.67%) = ½ *B.b.* + ½ Quinalphos (86.67%) < ½ *Ha*NPV + ½ *B.b.* (80.0%) < ½ *Btk* + ½ Azadirachtin (76.67%)< ½ *Ha*NPV+½ Azadirachtin (73.33%) = ½ Quinalphos + ½ Azadirachtin (73.33%) < ½ *B.b.* + ½ Azadirachtin (63.33%) < ½ *Btk*-sole (60.0%)< ½ *Ha*NPV-sole (56.67%) = ½ *B.b.*-sole (56.67%) = ½ Quinalphos-sole (56.67%)< ½ Azadirachtin-sole (46.67%).

Table 1: Details about individual treatments

S.N.	Treatments	Treatment Nature
T-1	*Btk* (0.75 Kg)	Low Dose
T-2	*Btk* (1.0 Kg)	Standard Dose
T-3	*Btk* (1.25 Kg)	High Dose
T-4	*B.b.* (1.5 Kg)	Low Dose
T-5	*B.b.* (2.5 Kg)	Standard Dose
T-6	*B.b.* (3.5 Kg)	High Dose
T-7	*Ha*NPV (150 LE)	Low Dose
T-8	*Ha*NPV (250 LE)	Standard Dose
T-9	*Ha*NPV (350 LE)	High Dose
T-10	Quinalphos (0.02%)	Low Dose
T-11	Quinalphos (0.04%)	Standard Dose
T-12	Quinalphos (0.06%)	High Dose
T-13	Azadirachtin (0.05%)	Low Dose
T-14	Azadirachtin (0.10%)	Standard Dose
T-15	Azadirachtin (0.15%)	High Dose
T-16	Control	Untreated

Table 2: Details about treatment combinations

S.N.	Treatments
T-1*	*Ha*NPV (125 LE) + *Btk* (0.5 Kg)
T-2*	*Ha*NPV (125 LE) + *B.b.* (1.25 Kg)
T-3*	*Ha*NPV (125 LE) + Quinalphos (0.02%)
T-4*	*Ha*NPV (125 LE) + Azadirachtin (0.05%)
T-5**	*Ha*NPV (125 LE)
T-6*	*Btk* (0.5 Kg) + *B.b.* (1.25 Kg)
T-7*	*Btk* (0.5 Kg) + Quinalphos (0.02%)
T-8*	*Btk* (0.5 Kg) + Azadirachtin (0.05%)
T-9**	*Btk* (0.5 Kg)
T-10*	*B.b.* (1.25 Kg) + Quinalphos (0.02%)
T-11*	*B.b.* (1.25 Kg) + Azadirachtin (0.05%)
T-12**	*B.b.* (1.25 Kg)
T-13*	Quinalphos (0.02%) + Azadirachtin (0.05%)
T-14**	Quinalphos (0.02%)
T-15**	Azadirachtin (0.05%)
T-16	Control

Note: * Combination with ½ of standard doses,
** Sole application with ½ of standard dose

Table 3: Independent effect of bio-pesticides & insecticide on larval mortality of *H. armigera* under chickpea field conditions (2010-11)

Treatments	Dose/ha	Cumulative mean % larval reduction at different days after treatments (DAT)				
		1 DAT (Mean)*	3 DAT (Mean)*	5 DAT (Mean)*	7 DAT (Mean)*	14 DAT (Mean)*
Btk	0.75 kg	0.0* (4.05)**	23.33 (28.78)	63.33 (53.07)	66.67 (55.07)	66.67 (55.07)
Btk	1.0 kg	0.0 (4.05)	30.00 (33.00)	73.33 (59.00)	86.67 (71.43)	90.00 (73.65)
Btk	1.25 kg	0.0 (4.05)	32.33 (34.93)	76.67 (61.92)	90.00 (73.65)	93.33 (76.36)
B. bassiana	1.5 kg	0.0 (4.05)	10.00 (16.35)	46.67 (42.99)	50.00 (45.00)	56.67 (48.93)
B. bassiana	2.5 kg	0.0 (4.05)	20.00 (26.07)	66.67 (55.07)	83.33 (68.72)	86.67 (71.43)
B. bassiana	3.5 kg	0.0 (4.05)	26.67 (30.99)	70.00 (56.00)	86.67 (71.43)	90.00 (73.65)
*Ha*NPV	150 LE	0.0 (4.05)	20.00 (26.07)	50.00 (45.00)	56.67 (48.93)	60.00 (50.85)
*Ha*NPV	250 LE	0.0 (4.05)	23.33 (28.07)	63.33 (53.07)	80.00 (63.93)	86.67 (71.43)
*Ha*NPV	350 LE	0.0 (4.05)	30.00 (33.00)	70.00 (56.99)	86.67 (71.43)	93.33 (76.36)
Quinalphos	0.02%	46.67 (42.99)	56.67 (48.93)	60.00 (50.85)	60.00 (50.85)	60.00 (50.85)
Quinalphos	0.04%	56.67 (48.93)	66.67 (55.07)	73.33 (59.71)	76.67 (61.92)	76.67 (61.92)
Quinalphos	0.06%	63.33 (53.07)	70.00 (56.99)	76.67 (61.92)	80.00 (63.93)	80.00 (63.93)
Azadirachtin	0.05%	03.33 (08.85)	10.00 (18.43)	30.00 (33.00)	43.33 (41.15)	46.67 (43.08)
Azadirachtin	0.10%	16.67 (11.55)	20.00 (26.07)	33.33 (34.93)	53.33 (47.01)	56.67 (48.93)
Azadirachtin	0.15%	20.00 (26.07)	23.33 (28.08)	46.67 (42.99)	60.00 (50.85)	63.33 (53.07)
Control	Untreated	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)
SEm±		3.43	4.33	4.75	5.65	5.45
CD at 5.0%		9.80	12.34	13.56	16.16	16.56

Note: * Mean of 3 replications, **Figures in parentheses are means of angular transformed values.

Table 4: Independent effect of bio-pesticides & insecticide on larval mortality of *H. armigera* under chickpea field conditions (2011-12)

Treatments	Dose/ha	Cumulative mean % larval reduction at different days after treatments (DAT)				
		1 DAT (Mean*)	3 DAT (Mean*)	5 DAT (Mean*)	7 DAT (Mean*)	14 DAT (Mean*)
Btk	0.75 kg	0.0* (4.05)**	16.67 (23.36)	43.33 (41.00)	50.00 (45.00)	60.00 (50.85)
Btk	1.0 kg	0.0 (4.05)	20.00 (26.07)	56.67 (48.93)	76.67 (61.92)	86.67 (71.43)
Btk	1.25 kg	0.0 (4.05)	26.67 (30.00)	70.00 (59.71)	83.33 (68.72)	93.33 (78.44)
B. bassiana	1.5 kg	0.0 (4.05)	06.67 (13.64)	26.67 (30.29)	40.00 (39.15)	46.67 (42.99)
B. bassiana	2.5 kg	0.0 (4.05)	13.33 (21.15)	40.00 (39.15)	63.33 (53.07)	70.00 (56.99)
B. bassiana	3.5 kg	0.0 (4.05)	20.00 (26.07)	50.00 (45.00)	66.67 (55.07)	80.00 (63.93)
*Ha*NPV	150 LE	0.0 (4.05)	10.00 (18.43)	36.67 (36.93)	43.33 (41.07)	53.33 (47.00)
*Ha*NPV	250 LE	0.0 (4.05)	16.67 (23.36)	46.67 (43.08)	73.33 (59.71)	83.33 (68.72)
*Ha*NPV	350 LE	0.0 (4.05)	23.33 (28.08)	63.33 (53.07)	80.00 (63.91)	90.00 (73.65)
Quinalphos	0.02%	20.00 (26.07)	30.00 (33.00)	46.67 (42.99)	53.33 (47.00)	53.33 (47.00)
Quinalphos	0.04%	33.33 (34.93)	53.33 (47.00)	66.67 (55.07)	76.67 (61.92)	76.67 (61.72)
Quinalphos	0.06%	46.67 (43.08)	63.33 (52.77)	76.67 (61.92)	83.33 (68.72)	83.33 (68.72)
Azadirachtin	0.05%	06.67 (13.65)	16.67 (23.85)	26.69 (30.99)	33.33 (34.93)	33.33 (34.93)
Azadirachtin	0.10%	13.33 (21.15)	23.33 (28.08)	33.33 (34.93)	40.00 (39.15)	46.67 (43.08)
Azadirachtin	0.15%	16.67 (23.85)	30.00 (33.00)	36.67 (36.93)	46.67 (42.99)	53.33 (47.00)
Control	Untreated	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)
SEm±		3.25	4.81	5.06	5.65	5.81
CD at 5.0%		9.27	13.72	14.44	16.11	16.58

Note: * Mean of 3 replications, **Figures in parentheses are means of angular transformed values.

Table 5: Interactive effect of bio-pesticides & insecticide on larval mortality of *H. armigera* under chickpea field conditions (2010-11)

Treatments	Cumulative mean % larval reduction at different days after treatments (DAT)				
	1 DAT (Mean)*	3 DAT (Mean)*	5 DAT (Mean)*	7 DAT (Mean)*	14 DAT (Mean)*
½ *Ha*NPV + ½ *Btk*	0.0* (4.05)**	33.33 (34.93)	60.00 (50.85)	90.00 (73.64)	93.33 (76.36)
½ *Ha*NPV + ½ *B.b.*	0.0 (4.05)	23.33 (28.08)	50.00 (45.07)	83.33 (66.14)	83.33 (66.14)
½ *Ha*NPV + ½ Quinalphos	30.0 (33.00)	60.00 (50.85)	83.33 (66.14)	90.00 (73.64)	90.00 (73.65)
½ *Ha*NPV + ½ Azadirachtin	16.67 (23.86)	40.00 (39.15)	60.00 (50.85)	80.00 (63.93)	80.00 (63.93)
½ *Ha*NPV (sole)	0.0 (4.05)	20.00 (26.07)	46.67 (42.99)	46.67 (42.99)	86.67 (70.93)
½ *Btk* + ½ *B.b.*	0.0 (4.05)	43.33 (41.15)	60.00 (50.85)	86.67 (70.93)	86.67 (70.93)
½ *Btk* + ½ Quinalphos	33.33 (34.93)	60.00 (50.85)	73.83 (59.71)	93.33 (73.55)	93.33 (76.36)
½ *Btk* + ½ Azadirachtin	20.0 (26.07)	53.33 (46.92)	60.00 (50.85)	83.33 (66.63)	86.67 (68.86)
½ *Btk* (sole)	0.0 (4.05)	26.67 (30.00)	53.33 (46.92)	53.33 (46.92)	53.33 (46.92)
½ *B.b.* + ½ Quinalphos	26.67 (30.99)	46.67 (42.99)	66.67 (55.07)	83.33 (66.64)	86.67 (68.85)
½ *B.b.* + ½ Azadirachtin	13.33 (21.15)	36.67 (36.93)	53.33 (47.01)	56.67 (48.93)	56.67 (48.93)
½ *B.b.* (sole)	0.0 (4.05)	20.00 (26.07)	43.33 (41.07)	43.33 (41.07)	46.67 (42.99)
½ Quinalphos+½ Azadirachtin	43.33 (41.07)	60.00 (50.85)	66.67 (55.07)	70.0 (56.99)	70.00 (56.99)
½ Quinalphos (sole)	36.67 (36.93)	46.67 (42.99)	50.00 (45.00)	50.00 (45.00)	50.00 (45.0)
½ Azadirachtin (sole)	10.0 (18.43)	23.33 (28.28)	36.67 (37.22)	36.67 (37.22)	36.67 (37.22)
Control	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)
SEm±	4.183	5.02	4.60	5.51	5.21
CD at 5%	11.80	14.15	12.98	15.55	14.69

Note: * Mean of 3 replications, **Figures in parentheses are means of angular transformed values.

Table 6: Interactive effect of bio-pesticides & insecticide on larval mortality of *H. armigera* under chickpea field conditions (2011-12)

Treatments	Cumulative mean % larval reduction at different days after treatments (DAT)				
	1 DAT (Mean)*	3 DAT (Mean)*	5 DAT (Mean)*	7 DAT (Mean)*	14 DAT (Mean)*
½ *Ha*NPV + ½ *Btk*	0.0* (4.05)**	26.67 (30.99)	66.67 (54.78)	86.67 (68.86)	90.00 (76.36)
½ *Ha*NPV + ½ *B.b.*	0.0 (4.05)	20.00 (26.07)	53.33 (46.92)	76.67 (61.22)	80.00 (63.93)
½ *Ha*NPV + ½ Quinalphos	33.33 (35.22)	66.67 (54.78)	86.67 (70.94)	86.67 (70.94)	86.67 (70.94)
½ *Ha*NPV + ½ Azadirachtin	13.33 (21.15)	46.67 (43.08)	63.33 (52.78)	66.67 (54.78)	73.33 (59.00)
½ *Ha*NPV (sole)	0.0 (4.05)	20.00 (26.07)	53.33 (46.92)	56.67 (48.85)	56.67 (48.85)
½ *Btk* + ½ *B.b.*	0.0 (4.05)	23.33 (28.78)	70.00 (56.99)	80.00 (63.93)	86.67 (70.94)
½ *Btk* + ½ Quinalphos	36.67 (37.22)	66.67 (54.78)	80.00 (63.93)	83.33 (66.15)	86.67 (68.86)
½ *Btk* + ½ Azadirachtin	23.33 (28.78)	56.67 (48.85)	63.33 (52.77)	73.33 (59.00)	76.67 (61.22)
½ *Btk* (sole)	0.0 (4.05)	33.33 (35.22)	56.67 (48.85)	60.00 (50.85)	60.00 (50.85)
½ *B.b.* + ½ Quinalphos	30.00 (33.00)	53.33 (46.92)	66.67 (54.78)	83.33 (66.15)	86.67 (68.86)
½ *B.b.* + ½ Azadirachtin	16.67 (23.86)	40.00 (39.15)	56.67 (48.93)	60.00 (48.93)	63.33 (52.77)
½ *B.b.* (sole)	0.0 (4.05)	23.33 (28.78)	46.67 (43.08)	53.33 (46.92)	56.67 (48.85)
½ Quinalphos + ½ Azadirachtin	40.00 (39.15)	66.67 (54.09)	70.00 (56.99)	73.33 (59.00)	73.33 (59.00)
½ Quinalphos (sole)	40.00 (39.15)	53.33 (46.92)	56.67 (48.85)	56.67 (48.85)	56.67 (48.85)
½ Azadirachtin (sole)	16.67 (23.86)	30.00 (33.00)	43.33 (41.15)	46.67 (43.08)	46.67 (43.08)
Control	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)	0.0 (4.05)
SEm±	2.55	2.91	3.34	3.52	3.39
CD at 5%	7.17	8.19	9.41	9.94	11.08

Note: * Mean of 3 replications, **Figures in parentheses are means of angular transformed values.

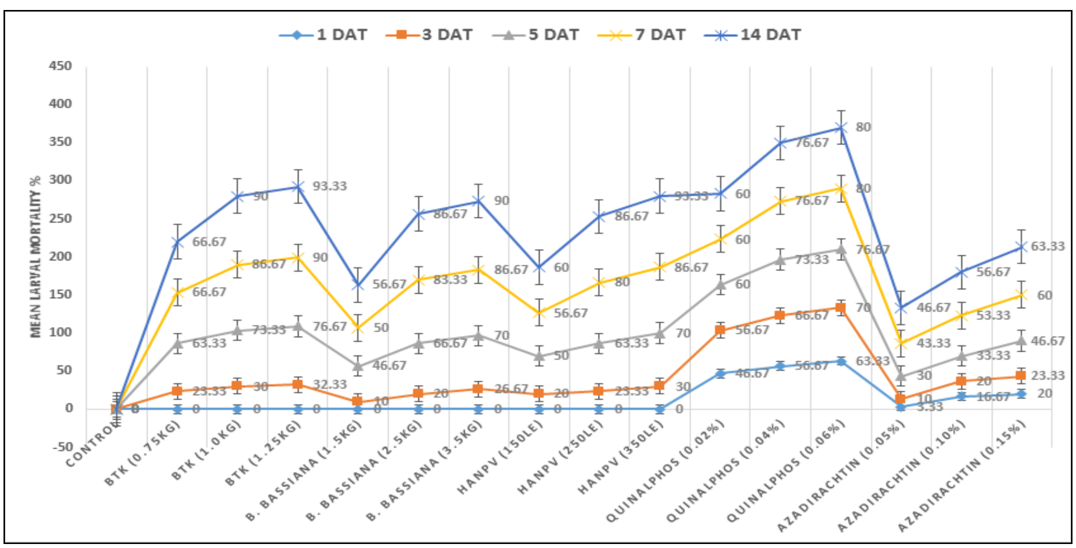

Fig.1: Independent effect of bio-pesticides and insecticide against *H. armigera* under field conditions (2010-11)

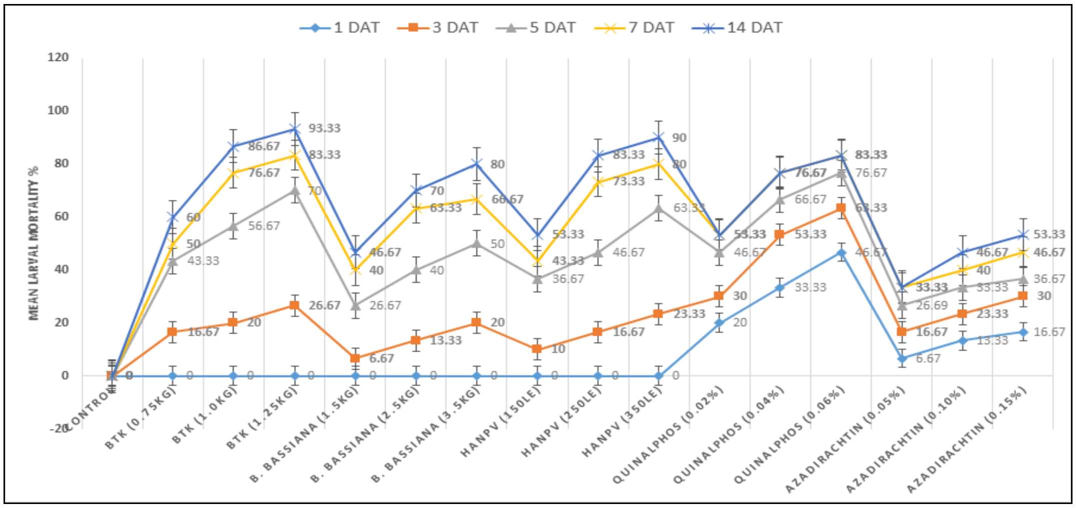

Fig 2: Independent effect of bio-pesticides and insecticide against *H. armigera* under field conditions (2011-12)

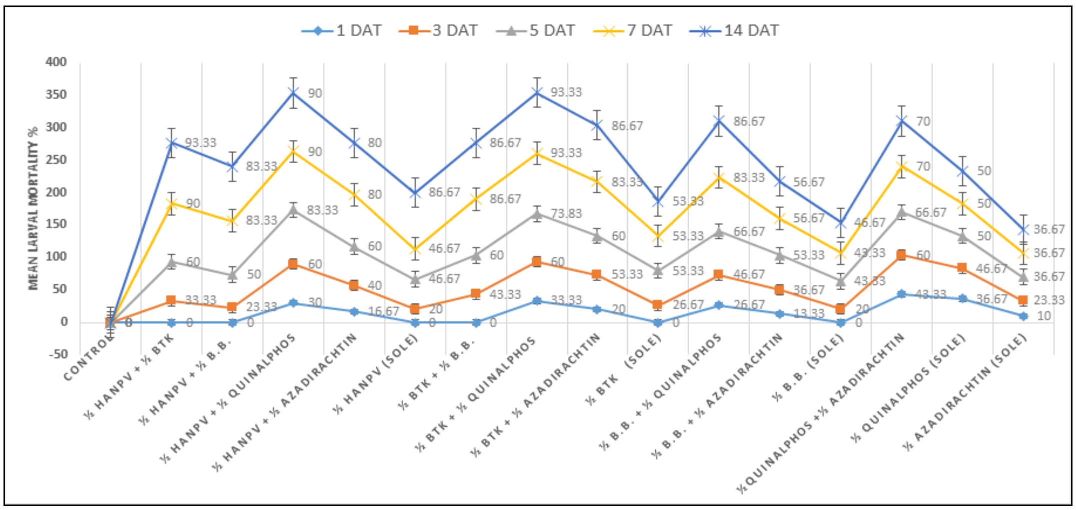

Fig 3: Interactive effect of bio-pesticides and insecticide against *H. armigera* under field conditions (2010-11)

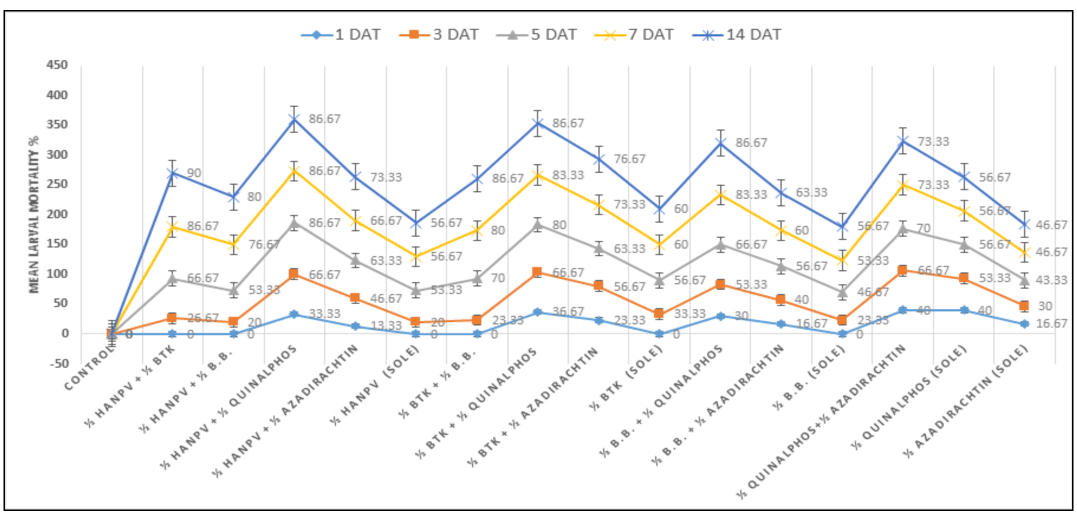

Fig 4: Interactive effect of bio-pesticides and insecticide against *H. armigera* under field conditions (2011-12)

4. Discussion

There is a strongly felt need among farmers either to minimal uses of synthetic pesticides with low doses or better to go towards biopesticides as sole treatments or as treatment combinations. In order to design a sustainable pest management model, the present study have tested several insecticides (biopesticides and synthetic) as sole treatments or in treatment combinations against 2nd instar larvae of the pest under chickpea field conditions during 2010-11 and 2011-12. Under sole treatments, the present study have tested biopesticides and insecticide at 3 doses (standard, high and low) duly recommended for per hectare of application. While under treatment combinations, we have tested mixed half standard doses of respective biopesticides and insecticide. In all experiments, the present study observed impact of such pesticide applications on larval mortality of the pest after 1st, 3rd, 5th, 7th, and 14th day.

The present study observed during both years that among all treatments, after 1st day, the high dose of Quinalphos (0.06%) had the highest larval mortality as 63.33% and low doses of Azadirachtin (0.05%) as the lowest as 3.33%. When many of the treatments with microbial (*Ha*NPV, *Btk*, and *Bb*) had no impact on larval mortality. Such results are in agreement with Bajya *et al.* [13] as they concluded that the Quinalphos 25% EC @ 1000 gm/ha is the most effective pesticide against the pest. It also supports a traditional thinking of our farmers that synthetic insecticides like Quinalphos is having quick knock down effect on the pest especially when used in higher concentration. Sole treatments of Azadirachtin did not prove much efficacy, however, found superior over sole and/or treatment combinations of *Ha*NPV, *Btk* and *Bb*. Other side, during second year, we witnessed the ½ Quinalphos + ½ Azadirachtin as the second best treatment with 40.0% larval mortality. Ahmed *et al.* [14] and Zahra *et al.* [15] have also concluded that the different concentrations of Azadirachtin had widely varying adverse effects on the fitness parameters of *H. armigera*. We observed a trend that treatment combinations of Azadirachtin, *Ha*NPV, *Btk* and *Bb* with Quinalphos had higher impact followed by microbial with Azadirachtin, during both the years.

The trend was moreover similar after 3rd day, but with a difference that all treatments were found superior over the untreated control. We observed that overall the high dose of Quinalphos (0.06%) had the highest larval mortality (70.0%), when low doses of *Bb* (1.5 kg) with the lowest as 6.67%. Besides this, we noticed that standard dose of Quinalphos (0.04%) was the second best among all with 66.67% efficacy. The key finding is that the treatment combinations of *Ha*NPV, *Btk* and Azadirachtin with Quinalphos were equally effective as standard dose of Quinalphos sole applications. Treatment combinations of *Ha*NPV, *Btk*, *Bb* with Azadirachtin were found better than their sole applications. This is in agreement with Sharma *et al.* [16] as they reported that incidence of *H. armigera* could be reduced by using combinations of Azadirachtin and *Ha*NPV with narrow range of contact and systemic insecticides. The increased date of treatment exposure had enhanced the pathogenicity of microbial and we witnessed a gradual improvement in terms of their efficacy. Therefore, after 5th day, sole applications and treatment combinations of microbial were observed as superior over the control.

Similarly, treatment combination of *Ha*NPV + Quinalphos recorded the highest larval mortality after 5th day as 86.67 and 83.33% during both the years. Jakhar and Suman [10] have also confirmed similar results after using *Ha*NPV and Quinalphos in tomato crop. High and standard doses of Quinalphos retained its top efficacy as sole and in combination with other pesticides (*Ha*NPV, *Btk*, *Bb* and Azadirachtin). Whereas half standard doses of Azadirachtin in combination with other pesticides were observed with medium level of efficacy and sole treatments of Azadirachtin (high, standard and low doses) had lowest impact on larval mortality. At par with Quinalphos (0.06%), *Btk* (1.25 kg) was observed as the second best treatment during first year with 76.67% efficacy. It also yielded good results in combination with other pesticides. We observed good results of microbial as sole and in combination with other pesticides with medium to high level of efficacy. Overall, treatment combinations were found superior over standard and low doses of most of the sole treatments.

However, the trend had changed after 7th day as most of the microbial with standard and high doses as sole or their treatment combinations were observed with top efficacy. Treatment combination of *Btk* + Quinalphos had the highest larval mortality as 93.33% followed by *Btk* (1.25 kg), *Ha*NPV + *Btk* and *Ha*NPV + Quinalphos as 90.0%. Such results are in conformity with Rahman *et al.* [17] that the lowest pod infestation was obtained after using treatments of *Ha*NPV and *Btk*. This is in agreement with Kumari *et al.* [18] that the *H. armigera* on chickpea could be effectively managed by the combination of *Btk* and *Ha*NPV. Whereas low dose of Azadirachtin (0.05%) had the lowest impact as 33.33%. However, standard and high dose of Azadirachtin had medium results as sole and in treatment combinations. High and standard doses of Quinalphos as sole application and in treatment combinations continued to give medium to high level of efficacy. Sole treatments of pesticides with standard and high doses resulted in high level of efficacy. We observed many of the treatment combinations most competitive in comparison to their sole treatments with low doses.

The trend after 7th day was moreover continued until 14th day. We observed that *Btk* (1.25 kg), *Ha*NPV (350 LE), *Ha*NPV + *Btk* and *Btk* + Quinalphos had the highest larval mortality as 93.33%. *Btk* (1.25 kg) has proved its highest efficacy with same potency (93.33%) in both the years. Therefore, keeping in view its continued efficacy in all 6 replications during both the years and eco-friendly characteristic, we are hereby concluding the *Btk* (1.25 kg) as the best treatment. This is in agreement with Chandra *et al.* [19] as they reported that all the concentrations of *Btk* products had adverse effect on growth and development of *H. armigera*. Similarly, Chandrasekran *et al.* [20] used different spore concentrations of *Btk* products and found that the growth rate of the pest was declined significantly. Such finding has good support from works of other researchers also. Therefore, the same is being recommended to farmers of this region (Bihar, India) for their general adoption in practice towards integrated management of *Helicoverpa armigera* (Hubner) on chickpea.

5. Conclusion

It was concluded that after 3rd to 14th days, all treatments were found superior over the untreated control (0.0%). Under independent and interactive studies, data received after 14th days of treatments revealed that *Btk* (1.25 kg), *Ha*NPV (350 LE), *Ha*NPV (125 LE) + *Btk* (0.5 kg), *Btk* (0.5 kg) + Quinalphos (0.02%) were observed with the highest mean larval mortality as 93.33%. *Btk* (1.25 kg) proved its highest efficacy with similar potency (93.33%) in both the years. Whereas, Azadirachtin (0.05%) was registered with the lowest mean larval mortality as 33.33%. Ultimately, this was also observed that *Btk*, *Ha*NPV & *B.b.* as alone or as treatment combinations were least effective during early days of application; however, after 7th day with increased days of treatment exposure, these were quite effective and the most competitive.

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