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Field evaluation of certain bio-pesticides against *Helicoverpa armigera* Hubner (Noctuidae: Lepidoptera) and its impact on pod damage and per plant yield of chickpea

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Abstract

Certain biopesticides (*Ha*NPV, *Btk*, *Bb*, Azadirachtin) and a synthetic insecticide (Quinalphos) were evaluated against *Helicoverpa armigera* to determine its impact on pod damage and per plant yield of chickpea during 2010-11 and 2011-12. Insecticides were applied as sole treatments and treatment combinations only once at the 50% flowering and podding stage of the crop. Upon the crop maturity, treatment combination of ½ *Btk* + ½ Azadirachtin was observed as the best overall treatment as it reduced pod damages of the crop as 10.24% & 10.42% against 43.77% & 46.43% in control. Consequently, it enhanced per plant yield the highest as 7.14 g & 7.25 g against 4.68 g & 4.89 g in control. Whereas, regarding least effective treatments, Quinalphos-0.02% was observed with the highest pod infestation as 17.28% & 17.51% and ½ *Bb* + ½ Azadirachtin with the minimum per plant yield as 5.73 g & 5.82 g

Keywords: Field evaluation, bio-pesticides, *Helicoverpa armigera,* pod damages, per plant yield, chickpea

1. Introduction

Pod borer *Helicoverpa armigera* Hubner (Noctuidae: Lepidoptera) is one of the major pest of gram. The pest starts its attack at early stage and become severe during maturity stage of the crop. The pest accounts for 90-95% of total damage [1, 2]. A single larva of *H. armigera* can damage 25-30 pods of gram in its life time [3]. It feeds on tender shoots and young pods [4]. It make holes in pods and insert its half body inside the pod to eat the developing seeds [5].

The pod borers inflict heavy crop losses from seedling to maturity and the losses reach at its peak when the pods appear [6, 7].

The seed yield losses due to *H. armigera* were 75-90% and in some places the losses were up to 100% [4]. The yield loss in chickpea due to pod borer was reported as 10 to 60 per cent in normal weather conditions, while it was 50 to 100 per cent in favourable weather conditions, particularly in the state where frequent rain and cloudy weather is prevailing during the crop season [8].These losses can be reduced by the application of insecticides [9, 10, 11, 12]. In favourable conditions pod borer may cause 90-95 per cent of pod damage [1].

Chickpea production is severely threatened by increasing difficulties in controlling the pod borers, *H. armigera* and *H. punctigera* [13]. The extent of losses due to *H. armigera* in chickpea has been estimated to be over $328 million in the semi-arid tropics [14]. Worldwide, losses due to *Heliothis/Helicoverpa* in cotton, legumes, vegetables, cereals, etc. may exceed $2 billion, and the cost of insecticides used to control these pests may be over $1 billion annually [15]. Field surveys in the early 1980s indicated that less than 10% of the farmers used pesticides to control *H. armigera* in chickpea in India [16]. However, the shift from subsistence to to control *H. armigera* in chickpea in India [16]. However, the shift from subsistence to commercial production and the resulting increase in prices have provided the farmers an opportunity to consider application of pest management options for increasing chickpea production [17].

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* to examine its impact on pod damage and per plant yield of chickpea.

2. Materials 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 1.0x10^7spores/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 0.1ml 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 formulae was used to prepare different concentrations of insecticides as suggested by Singh, 2015 [18].

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

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, observations were undertaken as per linear meter row. Treatments were applied only once at the time of 50% flowering and podding stage of the crop on 12th Feb. 2010 and 19th Feb. 2011. 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.

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

2.4 Statistical analysis

Upon time of the crop harvest (8th and 10th April during two subsequent years), for determination of pod infestation, 100 pods were collected randomly from plants of respective plots (treated and untreated) and recorded separately to work out the percentage of pod damage. Whereas, towards determination of per plant yield, up on the crop maturity, 10 plants were collected randomly from respective plots (treated and untreated) and sum total of their grain yield was obtained for further statistical analyses.
The data were subjected to statistical analysis after tabulation in to transformed values. 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 formulae were used for various estimations:

(1) Per cent pod damage $= \frac{\text{Damaged pod}}{\text{Total number of pod}} \times 100$

(2) Per plant yield (gm) $= \frac{\text{Total of grain yield from 10 plants (gm)}}{10}$

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

(4) Critical difference (C.D.) = S.E.M. x √ 2 x t 0.05

3. Results

3.1 Independent and interactive effect on pod damage during 2010-11

During 2010-11, all the treatments were superior over the control (38.38-46.43%) and the minimum pod damage (7.56%) was observed in case of *Ha*NPV-350 LE followed by *Ha*NPV-250 LE (8.62%), ½ *Ha*NPV + ½ *Btk* (9.46%). Other treatments had 9.91% to 17.51% of pod damages. Whereas Quinalphos-0.02% had the highest infestation of pods as 17.51% (Tables 3-4).

The increasing order of treatments regarding minimum to maximum mean percentage of pod damage were as *Ha*NPV-350 LE (7.56%) < *Ha*NPV-250 LE (8.62%) < ½ *Ha*NPV + ½ *Btk* (9.46%) < ½ *Ha*NPV + ½ Quinalphos (9.91%) < *Btk*-1.25 kg (10.12%) < Azadirachtin-0.15% (10.19%) < ½ *Btk* + ½ Azadiarctin (10.42%) < *Ha*NPV-150 LE (10.49%) < ½ *Ha*NPV + ½ *Bb* (10.53%) < ½ *Btk* + ½ Quinalphos (10.79%) < ½ *Ha*NPV + ½ Azadirachtin (10.92%) < Azadirachtin-0.10% (10.97%) < *Btk*-1.0 kg (11.01%) < *Bb*-3.5 kg (11.24%) < ½ Azadirachtin (11.36%) < ½ *Btk* + ½ *Bb* (11.86%) < ½ *Bb* + ½ Quinalphos (11.93%) < *Bb*-2.5 kg (12.21%) < ½ Quinalphos + ½ Azadirachtin (12.39%) < *Btk*-0.75 kg (12.42%) < ½ *Btk* (12.69%) < ½ *Ha*NPV (12.72%) < Quinalphos-0.06% (13.21%) < ½ *Bb* + ½ Azadirachtin (13.39%) < Azadirachtin-0.05% (13.44%) < *Bb*-1.5 kg (13.61%) < ½ *Bb* (13.81%) < Quinalphos-0.04% (14.84%) < ½ Quinalphos (16.78%) < Quinalphos-0.02% (17.51%).

Table 3: Independent effect of bio-pesticides & insecticide on *H. armigera* regarding pod damage of chickpea (2010-11 and 2011-12)

Treatments	Dose/ha	2010-11 Pod damage (%) (Mean)*	2011-12 Pod damage (%) (Mean)*	Pooled Mean
Btk	0.75 kg	12.42* (20.60)**	12.36 (20.55)	12.39 (20.58)
Btk	1.0 kg	11.01 (19.35)	11.13 (19.46)	11.07 (19.41)
Btk	1.25 kg	10.12 (18.50)	09.77 (18.16)	09.55 (18.33)
B. bassiana	1.5 kg	13.61 (21.63)	13.81 (21.79)	13.71 (21.71)
B. bassiana	2.5 kg	12.21 (20.44)	12.06 (20.31)	12.14 (20.38)
B. bassiana	3.5 kg	11.24 (19.52)	10.81 (19.15)	11.03 (19.34)
*Ha*NPV	150 LE	10.49 (18.33)	10.53 (18.91)	10.51 (18.87)
*Ha*NPV	250 LE	08.62 (17.01)	08.67 (17.05)	08.65 (17.03)
*Ha*NPV	350 LE	07.56 (15.94)	7.28 (15.61)	07.42 (15.78)
Quinalphos	0.02%	17.51 (24.71)	17.28 (24.55)	17.40 (24.63)
Quinalphos	0.04%	14.84 (22.64)	15.23 (22.95)	15.04 (22.79)
Quinalphos	0.06%	13.21 (21.81)	13.52 (21.55)	13.37 (21.42)
Azadirachtin	0.05%	13.44 (21.39)	13.55 (21.57)	13.50 (21.48)
Azadirachtin	0.10%	10.97 (19.30)	11.06 (19.39)	11.02 (19.35)
Azadirachtin	0.15%	10.19 (18.55)	10.38 (18.76)	10.29 (18.66)
Control	Untreated	38.38 (38.38)	42.39 (40.60)	40.49 (39.49)
SEm±		(0.92)	(0.76)	(0.84)
CD at 5.0%		(2.63)	(2.19)	(2.41)

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

Table 4: Interactive effect of bio-pesticides & insecticide on *H. armigera* regarding pod damage of chickpea (2010-11 & 2011-12)

Treatments	Mean*Pod damage (%) 2010-11	Mean*Pod damage (%) 2011-12	Pooled Mean
½ *Ha*NPV + ½ *Btk*	9.46* (17.83)**	9.48 (17.83)	9.47 (17.83)
½ *Ha*NPV + ½ *B.b.*	10.53 (18.89)	10.47 (18.78)	10.50 (18.84)
½ *Ha*NPV + ½ Quinalphos	9.91 (18.28)	9.89 (18.27)	9.90 (18.28)
½ *Ha*NPV + ½ Azadirachtin	10.92 (19.23)	10.72 (18.96)	10.82 (19.10)
½ *Ha*NPV (sole)	12.72 (20.87)	12.70 (20.72)	12.71 (20.80)
½ *Btk* + ½ *B.b.*	11.86 (20.13)	11.83 (20.07)	11.89 (20.10)
½ *Btk* + ½ Quinalphos	10.79 (19.11)	10.67 (18.94)	10.73 (19.03)
½ *Btk* + ½ Azadirachtin	10.42 (18.81)	10.24 (18.48)	10.33 (18.65)
½ *Btk* (sole)	12.69 (20.85)	12.46 (20.58)	12.57 (20.72)
½ *B.b.* + ½ Quinalphos	11.93 (20.15)	11.51 (19.71)	11.72 (19.93)
½ *B.b.* + ½ Azadirachtin	13.39 (21.45)	13.11 (21.17)	13.25 (21.31)
½ *B.b.* (sole)	13.81 (21.74)	13.56 (21.51)	13.73 (21.63)
½Quinalphos+½ Azadirachtin	12.39 (20.58)	12.21 (20.39)	12.30 (20.49)
½ Quinalphos (sole)	16.78 (24.13)	16.43 (23.89)	12.60 (24.01)
½ Azadirachtin (sole)	11.36 (20.99)	12.84 (20.94)	12.10 (20.96)
Control	46.43 (42.93)	43.77 (41.40)	45.10 (42.17)
SEm±	(1.02)	(1.46)	(1.24)
CD at 5%	(2.87)	(4.11)	(3.49)

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

3.2 Independent and interactive effect on pod damage during 2011-12

During 2011-12, all the treatments were superior over the control (42.39-43.77%) and the minimum pod damage (7.28%) was observed in case of *Ha*NPV-350 LE followed by *Ha*NPV-250 LE (8.67%), ½ *Ha*NPV + ½ *Btk* (9.48%). Other treatments had 9.77% to 17.28% of pod damages. Whereas Quinalphos-0.02% had the highest infestation of pods as 17.28%.

The increasing order of treatments regarding minimum to maximum mean percentage of pod damage were as *Ha*NPV-350 LE (7.28%) < *Ha*NPV-250 LE (8.67%) < ½ *Ha*NPV + ½

Btk (9.48%) < *Btk*-1.25 kg (9.77%) < ½ *Ha*NPV + ½ Quinalphos (9.89%) < ½ *Btk* + ½ Azadirachtin (10.24%) < Azadirachtin-0.15% (10.38%) < ½ *Ha*NPV + ½ *Bb* (10.47%) < *Ha*NPV-150 LE (10.53%) < ½ *Btk* + ½ Quinalphos (10.67%) < ½ *Ha*NPV + ½ Azadirachtin (10.72%) < *Bb*-3.5 kg (10.81%) < Azadirachtin-0.10% (11.06%) < *Btk*-1.0 kg (11.13%) < ½ *Bb* + ½ Quinalphos (11.51%) < ½ *Btk* + ½ *Bb* (11.83%) < *Bb*-2.5 kg (12.06%) < ½ Quinalphos + ½ Azadirachtin (12.21%) < *Btk*-0.75 kg (12.36%) < ½ *Btk* (12.46%) < ½ *Ha*NPV (12.70%) < ½ Azadirachtin (12.84%) < ½ *Bb* + ½ Azadirachtin (13.11%) < Quinalphos-0.06% (13.52%) < Azadirachtin-0.05% (13.55%) < ½ *Bb* (13.56%) < *Bb*-1.5 kg (13.81%) < Quinalphos-0.04% (15.23%) < ½ Quinalphos (16.43%) < Quinalphos-0.02% (17.28%).

3.3 Independent and interactive effect on per plant yield during 2010-11

During 2010-11, all the treatment combinations were superior over the control (4.68 g). Whereas, under independent effect, ½ *Bb*, ½ Azadirachtin and Azadirachtin-0.05% did not prove its efficacy over the control (5.73 g) (Tables 5-6).

The maximum per plant mean yield was observed in case of ½ *Btk* + ½ Azadirachtin (7.25 g) followed by Quinalphos-0.06% (7.23 g) and *Ha*NPV-350 LE (7.12 g). Other treatments yielded in a range from 5.82 g to 6.98 g. The treatment combination ½ *Bb* + ½ Azadirachtin recorded with the lowest per plant yield as 5.82 g.

The deceasing order of treatments regarding maximum to minimum mean per plant yield were as ½ *Btk* + ½ Azadirachtin (7.25 g) < Quinalphos-0.06% (7.23 g) < *Ha*NPV-350 LE (7.12 g) < Quinalphos-0.04% (6.98 g) = ½ Quinalphos + ½ Azadirachtin (6.98 g) < *Btk*-1.25 kg (6.96 g) < ½ *Ha*NPV + ½ Azadirachtin (6.94 g) < ½ *Ha*NPV + ½ Quinalphos (6.84 g) < *Ha*NPV-250 LE (6.75 g) < ½ *Btk* + ½ Quinalphos (6.63 g) < *Bb*-3.5 kg (6.57 g) < *Btk*-1.0 kg (6.53 g) < ½ *Ha*NPV + ½ *Btk* (6.49 g) < Azadirachtin-0.15% (6.37 g) < ½ *Ha*NPV + ½ *Bb* (6.35 g) < *Bb*-2.5 kg (6.28 g) < ½ Quinalphos (6.27 g) < ½ *Btk* + ½ *Bb* (6.24 g) < Quinalphos-0.02% (6.23 g) < ½ *Bb* + ½ Quinalphos (6.20 g) < *Ha*NPV-150 LE (6.19 g) < Azadirachtin-0.10% (6.10 g) < *Btk*-0.75 kg (6.08 g) < ½ *Ha*NPV (6.02 g) < ½ *Btk* (5.98 g) < *Bb*-1.5 kg (5.84 g) < ½ *Bb* + ½ Azadirachtin (5.82 g).

Table 5: Independent effect of bio-pesticides & insecticide on *H. armigera* regarding per plant yield of chickpea (2010-11 & 2011-12)

Treatments	Dose/ha	Mean*Yield (gm/plant)		Pooled Mean
		2010-11	2011-12	
Btk	0.75 kg	6.08	6.09	6.09
Btk	1.0 kg	6.53	6.63	6.58
Btk	1.25 kg	6.96	6.90	6.93
B. bassiana	1.5 kg	5.84	5.85	5.85
B. bassiana	2.5 kg	6.28	6.18	6.23
B. bassiana	3.5 kg	6.57	6.49	6.53
*Ha*NPV	150 LE	6.19	6.13	6.16
*Ha*NPV	250 LE	6.75	6.69	6.72
*Ha*NPV	350 LE	7.12	7.04	7.08
Quinalphos	0.02%	6.23	6.18	6.21
Quinalphos	0.04%	6.98	6.91	6.95
Quinalphos	0.06%	7.23	7.14	7.19
Azadirachtin	0.05%	5.51	5.41	5.46
Azadirachtin	0.10%	6.10	5.98	6.04
Azadirachtin	0.15%	6.37	6.27	6.32
Control	Untreated	5.73	5.61	5.67
SEm±		(0.239)	(0.221)	(0.23)
CD at 5.0%		(0.684)	(0.632)	(0.658)

Note: * Mean of 3 replications.

Table 6: Interactive effect of bio-pesticides & insecticide on *H. armigera* regarding per plant yield of chickpea (2010-11 & 2011-12)

Treatments	Mean*Yield (gm/plant)		Pooled Mean
	2010-11	2011-12	
½ *Ha*NPV + ½ *Btk*	6.49	6.42	6.45
½ *Ha*NPV + ½ *B.b.*	6.35	6.25	6.30
½ *Ha*NPV + ½ Quinalphos	6.84	6.78	6.82
½ *Ha*NPV + ½ Azadirachtin	6.94	6.68	6.81
½ *Ha*NPV (sole)	6.02	5.96	5.99
½ *Btk* + ½ *B.b.*	6.24	6.12	6.18
½ *Btk* + ½ Quinalphos	6.63	6.59	6.61
½ *Btk* + ½ Azadirachtin	7.25	7.14	7.19
½ *Btk* (sole)	5.98	5.87	5.92
½ *B.b.* + ½ Quinalphos	6.20	6.14	6.17
½ *B.b.* + ½ Azadirachtin	5.82	5.73	5.77
½ *B.b.* (sole)	5.72	5.61	5.66
½Quinalphos+½ Azadirachtin	6.98	6.85	6.92
½ Quinalphos (sole)	6.27	6.19	6.23
½ Azadirachtin (sole)	5.55	5.61	5.58
Control	4.68	4.89	4.79
SEm±	(0.229)	(0.234)	(0.231)
CD at 5%	(0.648)	(0.663)	(0.655)

Note: * Mean of 3 replications.

3.4 Independent and interactive effect on per plant yield during 2011-12

During 2011-12, all the treatment combinations were superior over the control (4.89 g). Whereas, under independent effect, Azadirachtin-0.05% did not prove its efficacy over the control (5.67 g) and ½ Azadirachtin was at par with the control.

The maximum per plant mean yield was observed in case of ½ *Btk* + ½ Azadirachtin (7.14 g) followed by Quinalphos-0.06% (7.14 g) and *Ha*NPV-350 LE (7.04 g). Other treatments yielded in a range from 5.73 g to 6.91 g. The treatment combination ½ *Bb* + ½ Azadirachtin recorded with the lowest per plant yield as 5.73 g.

The deceasing order of treatments regarding maximum to minimum mean per plant yield were as ½ *Btk* + ½ Azadirachtin (7.14 g) < Quinalphos-0.06% (7.14 g) < *Ha*NPV-350 LE (7.04 g) < Quinalphos-0.04% (6.91 g) < *Btk*-1.25 kg (6.90 g) < ½ Quinalphos + ½ Azadirachtin (6.85 g) < ½ *Ha*NPV + ½ Quinalphos (6.78 g) < *Ha*NPV-250 LE (6.69 g) < ½ *Ha*NPV + ½ Azadirachtin (6.68 g) < *Btk*-1.0 kg (6.63 g) < ½ *Btk* + ½ Quinalphos (6.59 g) < *Bb*-3.5 kg (6.49 g) < ½ *Ha*NPV + ½ *Btk* (6.42 g) < Azadirachtin-0.15% (6.27 g) < ½ *Ha*NPV + ½ *Bb* (6.25 g) < ½ Quinalphos (6.19 g) < *Bb*-2.5 kg (6.18 g) < Quinalphos-0.02% (6.18 g) < ½ *Bb* + ½ Quinalphos (6.14 g) < *Ha*NPV-150 LE (6.13 g) < ½ *Btk* + ½ *Bb* (6.12 g) < *Btk*-0.75 kg (6.09 g) < Azadirachtin-0.10% (5.98 g) < ½ *Ha*NPV (5.96 g) < ½ *Bb* (5.87 g) < ½ *Btk* (5.87 g) < *Bb*-1.5 kg (5.85 g) < ½ *Bb* + ½ Azadirachtin (5.73 g).

4. Discussion

In order to design a sustainable pest management model, we 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, we 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, upon the crop maturity, we have observed impact of such pesticide applications on pod infestation and per plant yield of the crop.

4. Determination of pod infestation

Regarding pod infestation, we have observed almost the very similar trend during both the years. The *Ha*NPV-350 LE and Quinalphos-0.02% were registered with the lowest and the highest pod infestation respectively during both the years. Similarly, the lowest pod infestation with *Ha*NPV have been reported by Sharma *et al.* [19] Ahmed *et al.* [20] Rahman *et al.* [21] Jakhar and Suman [22] Ahmed and Chandel [23] Kumari *et al.* [24]. Sole treatments of *Ha*NPV with high, standard and low dose had low infestation, whereas, its half dose had high level of pod infestations **(**Figures 1-2).

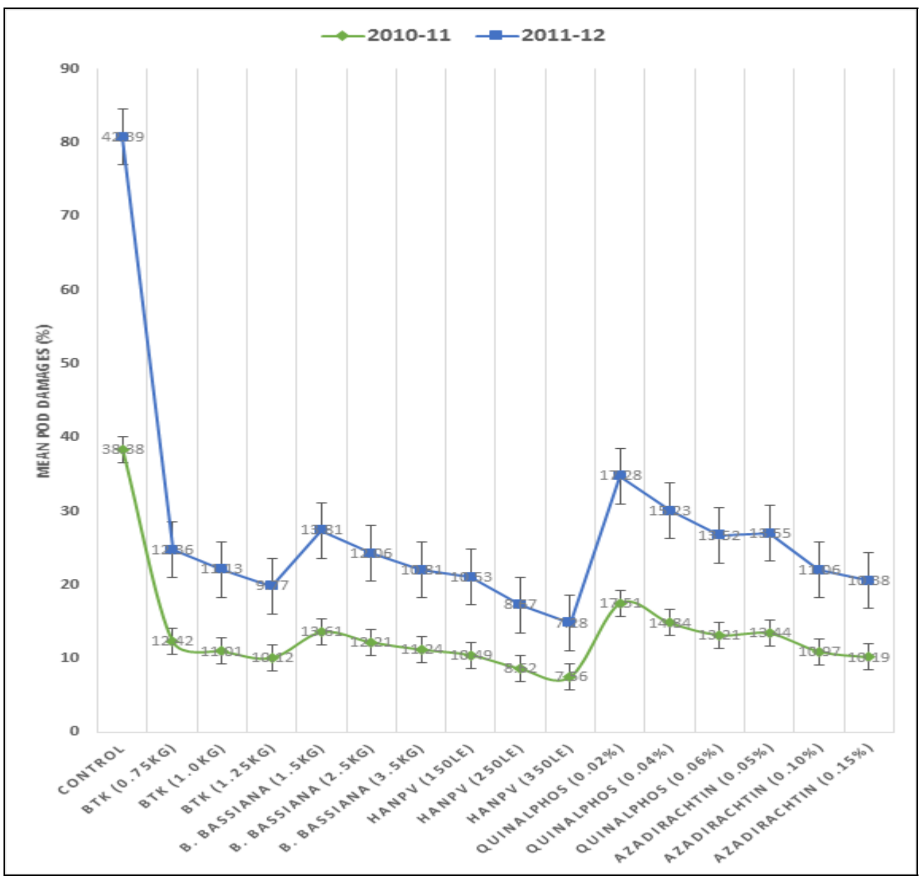

Fig 1: Independent effect of bio-pesticides and insecticide against *H. armigera* regarding pod damage of chickpea (2010-11 and 2011-12)

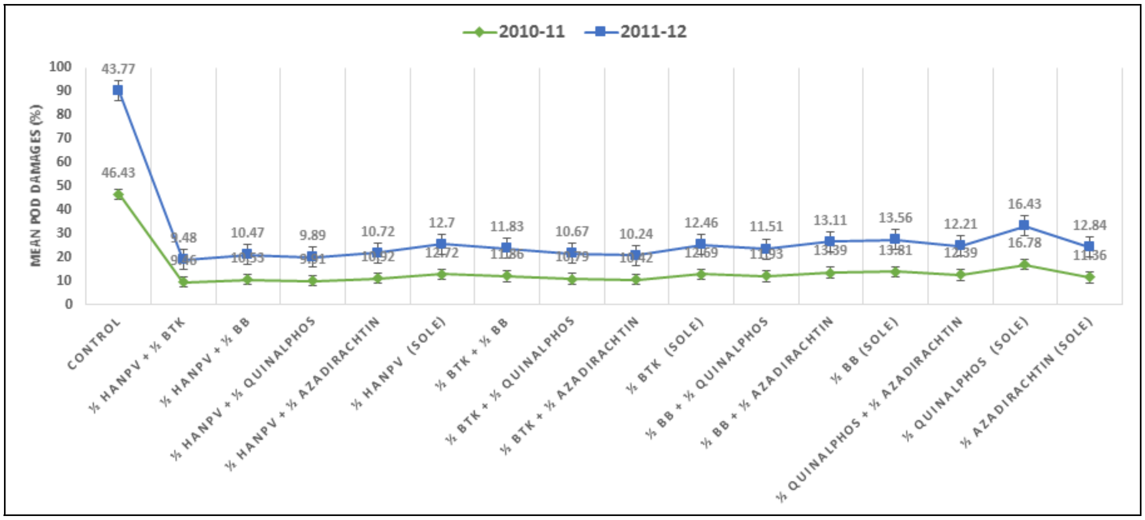

Fig.2: Interactive effect of bio-pesticides and insecticide against *H. armigera* regarding pod damage of chickpea (2010-11 and 2011-12)

We found the *Btk* as the second best pesticide. The high dose of *Btk*-1.25 kg was the 5th and 4th best treatment during first and second year for reduction in pod infestation, whereas as treatment combination with *Ha*NPV, during both the years, it was the 3rd best. Chandra *et al.* [25] Rahman *et al.* [21] Kumari *et al.* [24] Chandrasekran *et al.* [26] Golvankar *et al.* [27] have good support for this observation with *Btk* uses. Standard, low and half dose of *Btk* registered with the medium level of pod infestation.

We observed the *Beauveria bassiana* (*Bb*) as the 3rd best pesticide, as sole treatment with high and standard dose it had medium level of infestation, whereas it's low and half dose was registered with heavy pod infestation. Bajya *et al.* [28] and Suneel *et al.* [29] have also reported similar observation with *Bb*. However, as treatment combination, the *Bb* has shown rather low to medium level of pod infestation.

Azadirachtin was observed as the 4th best pesticide, as its high and standard dose had low and medium level of infestation, and its low dose was registered with heavy infestation. Sharma *et al.* [19] Ahmed *et al.* [20] Zahra *et al.* [30] Reza [31] Hossain [32] have also confirmed good results of Azadirachtin for minimising pod infestation. However, in treatment combination with other pesticides, it was observed with low to medium level of efficacy.

We observed the Quinalphos sole treatments as the least effective pesticide, as its all doses were registered with heavy pod infestation. However, in treatment combination with other pesticides it showed low to medium level of pod infestation. Lal and Jat [33] have also concluded that Quinalphos 25EC @ 1000 ml/ha had no consistent results against *H. armigera*.

Microbials well played their role in reducing the pod infestation. Treatment combinations of most of pesticides were observed with better results in comparison to their sole treatments with low doses. Almost all treatment combinations of pesticides (*Ha*NPV, *Btk*, *Bb*, Quinalphos, and Azadirachtin) had low to medium level of pod infestations.

4.2 Determination of per plant yield

We noticed the maximum per plant (mean) yield with treatment combination of ½ *Btk* + ½ Azadirachtin, followed by Quinalphos-0.06%, *Ha*NPV-350 LE and Quinalphos-0.04% during both the years (Figures 3-4).

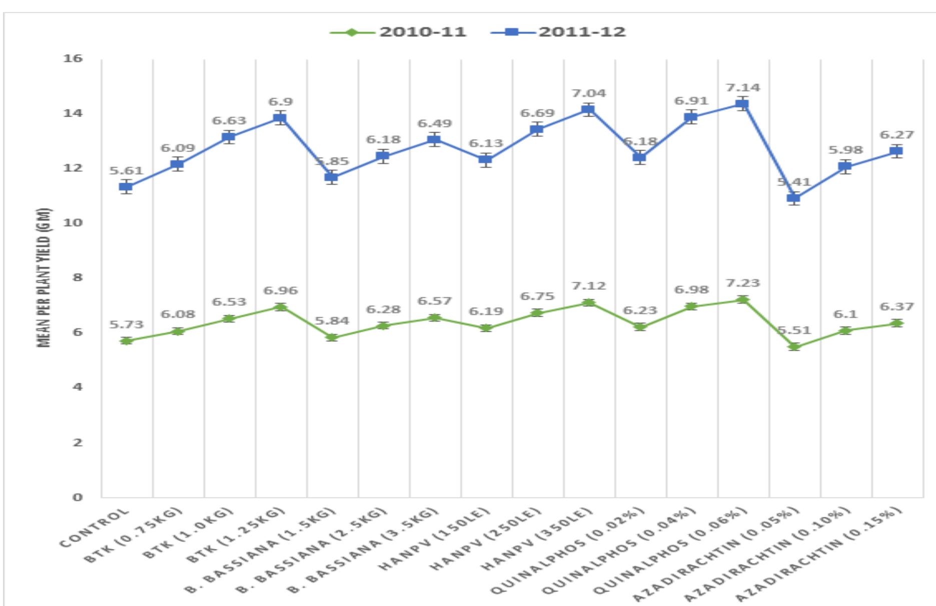

Fig 3: Independent effect of bio-pesticides and insecticide against *H. armigera* regarding per plant yield of chickpea.

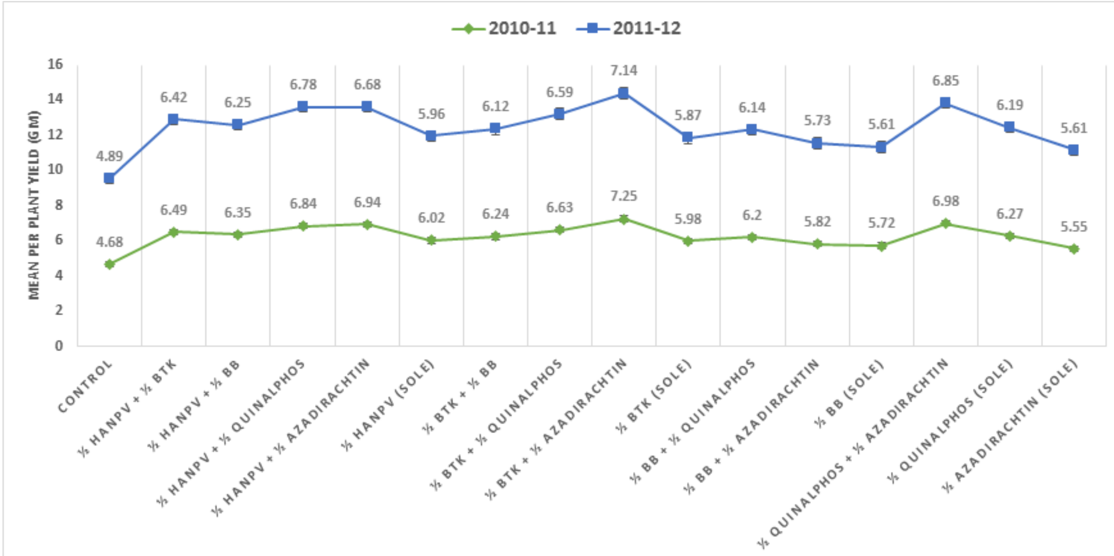

Fig 4: Interactive effect of bio-pesticides and insecticide against *H. armigera* regarding per plant yield of chickpea (2010-11 and 2011-12).

However, again we experienced moreover similar results. Regarding per plant yield, we witnessed quite good results of *Btk*. Chandra *et al.* [25] Rahman *et al.* [21] Kumari *et al.* [24] Chandrasekran *et al.* [26] Golvankar *et al.* [27] have also confirmed such observations. *Btk* sole treatments with high and standard doses were registered with high yield, when its most of the treatment combinations with other pesticides had high to medium yield. Although, its low and half doses did not prove much efficacy.

We observed the Quinalphos as the second best pesticide in terms of per plant yield. The sole treatments of Quinalphos with high and standard doses were registered with high yield, when its low dose had medium yield. Similarly, most of its treatment combination with other pesticides gave high to medium yield. Lal and Jat [33] Bajya *et al.* [28] are in conformity with such results.

The next effective pesticide we observed was the *Ha*NPV. The sole treatments of *Ha*NPV with high and standard doses had high to medium yield, when its low and half doses did not prove much efficacy. However, in most of the treatment combinations it gave high to medium yield. Ahmed *et al.* [20] Rahman *et al.* [21] Jakhar and Suman [22] Ahmed and Chandel [23] Sharma *et al.* [19] Kumari *et al.* [24] have also confirmed high per plant yield with *Ha*NPV.

We noticed the minimum yield with treatment combination of ½ *Bb* + ½ Azadirachtin, during both the years. Suneel *et al.* [29] concluded the lowest per plant yield with such treatment combination. Similarly, except high dose, the sole treatments of Azadirachtin with standard and low doses did not prove much efficacy. However, as treatment combinations in most of the cases, it gave high to medium yield. Ahmed *et al.* [20] and Zahra *et al.* [30] have also confirmed good results of Azadirachtin in terms of per plant yield.

As per our observation, we noticed the *Bb* as the least effective pesticide, in terms of per plant yield, as none of its applications (sole or treatment combinations) were determined with high yield. Similarly, Suneel *et al.* [29] have recorded the lowest yield with *Bb* treatments.

5. Conclusion

After going through, experimental results of sole treatments (with high, standard, low/half doses) and treatment combinations of pesticides and their impact on pod infestation and per plant yield of chickpea, we have concluded the treatment combination of ½ *Btk* + ½ Azadirachtin as the best overall treatment. Our results have established its significantly high efficacy while minimising pod infestation and finally in terms of per plant yield, it was the best among 30 treatments during both the years. Such result has good support from similar research works of current and earlier researchers. Moreover, being a treatment combination comprising a rather safe microbe (*Btk*) and a biorational (Azadirachtin) with half of standard doses, would be comparatively safer to the environment. Therefore, we hereby recommend the treatment combination of ½ *Btk* + ½ Azadirachtin to our farmers for its suitable incorporation towards integrated management of *Helicoverpa armigera* in chickpea.

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