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Bio-efficacy of different insecticides against pod borer, *Helicoverpa armigera* infesting Pigeon pea

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Abstract
Investigation was carried out on management of *Helicoverpa armigera* (Hubner) on pigeon pea, during the *kharif* 2019-20 at Agronomy Instructional Farm, S. D. Agricultural University, Sardarkrushinagar to evaluate the efficacy of different eight insecticides. Among the various insecticides the lower larval population of *H. armigera* was observed when crop was treated with Chlorantraniliprole 18.5 SC (0.006%) which was remain at par with Flubendiamide 480 SC (0.050%), Emamectin benzoate 5 SG (0.003%) and Lambda-cyhalothrin 5% EC (0.005%). The higher pod yield was obtained when crop was treated with Chlorantraniliprole 18.5 SC (0.006%) however, it has remained at par with Flubendiamide 480 SC (0.050%). The lower pod yield was obtained in untreated crop, which was remained at par with Azadirachtin 1500 ppm (0.00075%), *Beauveria basssiana* 1.15 WP (2 x 10^8 cfu/gm) (0.0046%) and HaNPV (1 x 10^{10} POB/ml) (250 LE/ha). The highest Protection Cost: Benefit Ratio (PCBR) was obtained in plots treated with Emamectin-benzoate 5 SG (0.003%) (PCBR=1:10.77) and quinalphos 25 EC (0.05%) (PCBR=1:9.20). The lowest (PCBR 1:0.98) was calculated in the treatment of *Beauveria basssiana* 1.15 WP [(2 x 10^8 cfu/gm) (0.0046%)].

Keywords: Pigeon pea, *Cajanus cajan*, pod borer, *Helicoverpa armigera*, yield

Introduction
Pigeon pea (*Cajanus cajan* (L.) Millspaugh) is one of the major pulse crops of the tropics and subtropics. It is the second most important pulse crop of India, after chickpea (Nene *et al.*, 1990) [7]. It is grown in kitchen markets and truck gardens. It is commonly known as arhar in Hindi, tuver in Gujarati and popularly known as red gram in English. It is used as a *dhal* (split seed); green seeds are used as a vegetable. Crushed dry seeds used as animal feed, green and dry leaves as fodder, stems as fuelwood and to make huts and baskets in the tribal area, etc. Indians, in general, prefer vegetarian food and one of the main sources of getting protein is the pulses. It is an agricultural crop of rainfed-dry lands, which can be grown on mountain slopes to reduce soil erosion.

Per capita availability of pulses is very low (47.9 gm/capita/day) as compared to optimum (80 g/capita/day) as per WHO standard, (Anon., 2018a) [2]. The productivity of pigeon pea in comparison to cereals is very low and stagnated due to several biotic and abiotic stresses, therefore, concerted efforts require for enhancing its production. Globally, it is cultivated in a total area of 6.99 million hectares with an annual production of 5.96 million tonnes (Mt) and productivity is around 852 kg/ha (Anon., 2018b) [3]. In India, it occupies an area of 5.52 million hectares with a production and a productivity of 4.26 million tons and 792 kg/ha, respectively (Anon., 2019a) [4]. India has the largest acreage and production of pigeon pea. About 74.76 per cent of the total global area falls in India with corresponding 63.7 per cent of global production (Anon., 2016) [1]. The major pigeon pea growing states in India are Madhya Pradesh (0.84 Mt), Maharashtra (1.13 Mt), Karnataka (0.76 Mt), Uttar Pradesh (0.33 Mt) and Gujarat (0.34 Mt). Pigeon pea is grown throughout the country except for the hilly regions where winter temperature is very low.

In Gujarat, pigeon pea is grown under 254 lakh hectares with an annual production of 307 lakh tonnes leading to the productivity of 1209 kg/ha (Anon., 2019b) [5]. Pigeon pea is mainly cultivated as a sole crop in Bharuch, Vadodara, Anand, Kheda, Panchmahal, Dahod, Mahisagar, Sabarkantha, Aravalli, Banaskantha, Valsad, and Ahmedabad districts. However, it is also intercropped with maize, sesamum, groundnuts, etc., especially in Saurashtra and eastern tribal belt of Gujarat.

The most economical pests those attack at the flowering and podding stage of the crop are pigeon pea pod borer, *Helicoverpa armigera* (Hubner); blue butterflies, *Lampides boeticus* L. and *Catochrysops strabo* (Fabricius); plume moth, *Exelastis atomosa* (Walsingham) and pod fly, *Melanagromyza obtusa* Malloch (Reed *et al*., 1989) [10]. Pod borers cause huge annual losses, especially to the poorest farmers who cannot afford chemical control. Considerable loss in grain yield is inflicted on account of their association with fruiting bodies. Pod borers have been estimated to cause 60 to 90 per cent loss in the grain yield of pigeon pea under favourable conditions and the damage of seeds by pod fly generally ranges between 14.3 to 46.6 per cent (Priyadarshini *et al*., 2013) [8].

To control this pest, there are number of different insecticides are present in market. In this context, the present study was carried out to the efficacy of fewer insecticides under field condition for their comparative efficacy against pigeonpea pod borer.

Materials and Methods

Field experiment was carried out at Agronomy instructional farm, S. D. Agricultural University, Sardarkrushinagar, Gujarat during *kharif*, 2019. The crop was raised by adopting standard agronomical practices. To evaluate efficacy, pigeonpea variety GT 103 was planted on plot size 4.5 x 2.0 m. with plant to plant spacing of 20 cm and row to row spacing of 90 cm. The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments details are as follow:

Table 1: The experiment was laid out in Randomized Block Design (RBD) with three replications

Sr. No.	Treatment	Concentration (%)	Dose (ml or g/ 10 lit. of water)
1	Chlorantraniliprole 18.5 SC	0.006	3 ml
2	Lambda-cyhalothrin 5 EC	0.005	10 ml
3	Flubendiamide 480 SC	0.050	2 ml
4	Emamectin-benzoate 5 SG	0.003	5 g
5	Quinalphos 25 EC	0.050	20 ml
6	HaNPV (1 x 10^{10} POB/ml)	250 LE/ha	10 ml
7	*Beauveria basssiana* 1.15 WP (2 x 10^8fu/gm)	0.0046	40 g
8	Azadirachtin 1500 PPM	0.00075	50 ml
9	Control (Untreated)	-	-

Various insecticides were given by using high volume sprayer (knapsack) with required concentration. From each treatment plot, 5 plants were selected randomly and to find out the efficacy of different insecticides the larvae of pigeon pea pod borer (*H. armigera*) were recorded from tagged plants. The observations were recorded before spraying as well 3, 7 and 10 days after spray. First spray was given on appearance of the pest and second spray was given after 15 day of the first spray. The number of pods damaged by *H. armigera* was recorded at harvest and per cent damage was worked out and the yield data were recorded. Data thus obtained were subjected to ANOVA after following the appropriate transformation to see the impact of various insecticides on activity of pigeon pea pod borer larvae (Steel and Torrie, 1980) [11].

The pigeon pea was harvested at maturity and yield (kg/plot) were recorded from each net plot area under each treatment. Yield recorded from each net plot was converted in to hectare basis for comparison. The increase in yield over control was worked out by following formula given by Khosla (1977) [6].

$$\text{Increase in yield over control (\%)} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

$$\text{Avoidable loss (\%)} = \frac{\text{Highest yield in treated plot} - \text{Yield in control}}{\text{Highest yield in treated plot}} \times 100$$

Results and Discussion

Observations recorded on number of larvae/plant on one day before spray, 3, 7 days and 10 days after first and second spray was recorded and presented in The data of pooled over periods presented in Table 2 which conclude that there was significant difference among various insecticides. Pod damage % presented in Table 3. Yield, increase in yield and avoidable loss of pigeon pea in different insecticidal treatments was presented in Table 4. Economics of different treatments during *kharif* 2019-20 in pigeon pea described in Table 5. Only significant findings are presented and discussed below.

i) Efficacy of different insecticides

The data presented in Table 2 revealed that in before spray uniform population of larvae of pod borer in all the treatments which was found non-significant. The average population ranged from 4.18 to 4.34 pigeon pea pod borer/5 plants.

The result indicate that the lower larval population of *H. armigera* was observed when crop was treated with chlorantraniliprole 18.5 SC (0.006%) which was remain at par with flubendiamide 480 SC (0.05%), emamectin benzoate 5 SG (0.003%) and lambda-cyhalothrin 5% EC (0.005%) followed by quinalphos 25 EC (0.05%), HaNPV (1 x 10^{10} POB/ml) (250 LE/ha), *Beauveria basssiana* 1.15 WP (2 x 108 cfu/gm) (0.0046%) and azadirachtin 1500 ppm (0.00075%).

The treatment Azadirachtin 1500 ppm (0.00075%), *Beauveria basssiana* 1.15 WP [(2 x 10^8 cfu/gm) (0.0046%)] and HaNPV (1 x 10^{10} POB/ml) (250 LE/ha) found less effective at three, seven and ten days after first and second spray respectively to control *H. armigera* in pigeon pea. The maximum larval population was observed in the untreated crop. The chlorantraniliprole 18.5 SC (0.006%) and flubendiamide 480 SC (0.05%) were found superior and equally effective at three, seven and ten days after first and second spray respectively to protect the pods against pigeon pea pod borer (*H. armigera*) at harvest (Table 2).

Similar to the present finding, Rani *et al.* (2018) [9] reported chlorantraniliprole 18.5 SC (0.006%) as effective and at par with flubendiamide 480 SC (0.05%) against *H. armigera*

Table 2: Efficacy of different insecticides against *H. armigera* on pigeon pea

Tr. No.	Treatment	Dose (ml or g/ 10 lit. of water)	*H. armigera* larvae per five plants						
			Before spray	1st Spray			2nd Spray		
				3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS
T_1	Chlorantraniliprole 18.5 SC	3	2.18 (4.23)	1.40^{a} (1.46)	1.22^{a} (1.00)	1.23^{a} (1.02)	1.01^{a} (0.53)	0.79^{a} (0.13)	0.83^{a} (0.19)
T_2	Lambda-cyhalothrin 5 EC	10	2.17 (4.20)	1.65^{abc} (2.22)	1.47^{b} (1.65)	1.47^{b} (1.65)	1.40^{c} (1.47)	1.25^{c} (1.06)	1.28^{c} (1.13)
T_3	Flubendiamide 480 SC	2	2.20 (4.32)	1.56^{ab} (1.93)	1.38^{ab} (1.40)	1.39^{ab} (1.43)	1.17^{ab} (0.87)	0.95^{ab} (0.40)	0.98^{ab} (0.46)
T_4	Emamectin-benzoate 5 SG	5	2.16 (4.18)	1.64^{abc} (2.20)	1.44^{ab} (1.59)	1.46^{b} (1.64)	1.24^{bc} (1.05)	1.11^{bc} (0.73)	1.13^{bc} (0.79)
T_5	Quinalphos 25 EC	20	2.20 (4.34)	1.71^{bcd} (2.43)	1.60^{bc} (2.05)	1.62^{b} (2.12)	1.42^{c} (1.52)	1.28^{c} (1.13)	1.32^{c} (1.24)
T_6	HaNPV (1 x 10^{10} POB/ml)	10	2.18 (4.24)	1.88^{cde} (3.04)	1.81^{cd} (2.77)	1.85^{c} (2.93)	1.83^{d} (2.86)	1.73^{d} (2.51)	1.76^{d} (2.59)
T_7	*Beauveria basssiana* 1.15WP (2 x 10^8 cfu/gm)	40	2.20 (4.34)	1.95^{def} (3.31)	1.94^{d} (3.26)	1.96^{c} (3.33)	1.92^{d} (3.17)	1.83^{d} (2.86)	1.85^{d} (2.92)
T_8	Azadirachtin 1500 ppm	50	2.18 (4.25)	1.99^{ef} (3.46)	1.97^{d} (3.40)	2.01^{c} (3.53)	1.97^{d} (3.39)	1.94^{d} (3.25)	1.96^{d} (3.32)
T_9	Control (Untreated)	-	2.20 (4.34)	2.21^{f} (4.38)	2.23^{e} (4.45)	2.24^{d} (4.53)	2.27^{e} (4.67)	2.28^{e} (4.70)	2.29^{e} (4.73)
S. Em. ±			0.11	0.08	0.07	0.07	0.07	0.07	0.07
C.V. %			7.85	7.48	7.14	7.20	8.36	9.54	9.34

Figures in parentheses are $\sqrt{x+0.5}$ retransformed values. DAS=Days after Spray. Treatment means with the superscript letter/letters in common are not significant by DNMRT at 5% level of significance.

ii) Pod damage (%) at harvest

The mean data of *kharif*, 2019-20 revealed that the pod damage (%) of *H. armigera* varied from 6.92 to 26.10 per cent. The highest pod damage (%) was noticed in untreated control plot with 26.10 per cent (Table 3). All the insecticides expressed significant difference among them and proved superior over control in reducing pod damage (%). Among all, chlorantraniliprole 18.5 SC showed lower pod damage (6.92%) of *H. armigera*. The other insecticides also exhibited superior reduction of pod damage over control and their efficacy order is flubendamide 480 SC (9.00%), emamectin-benzoate 5 SG (10.01%) < lambda-cyhalothrin 5 EC (10.51%) < quinalphos 25 EC (11.40%) < HaNPV (1 x 10^{10} POB/ml) (18.36%) < *Beauveria basssiana* 1.15WP (2 x 10^8 cfu/gm) (19.36%) < azadirachtin 1500 PPM (20.67%).

Table 3: Pod damage (%) by *H. armigera* in various treatment of pigeon pea during *Kharif* 2019-20

Tr. No.	Treatments	Pod damage (%) at harvest
T_1	Chlorantraniliprole 18.5 SC	15.25^{a} (6.92)*
T_2	Lambda-cyhalothrin 5 EC	18.92^{ab} (10.51)
T_3	Flubendiamide 480 SC	17.46^{b} (9.00)
T_4	Emamectin-benzoate 5 SG	18.44^{b} (10.01)
T_5	Quinalphos 25 EC	19.73^{b} (11.40)
T_6	HaNPV (1 x 10^{10} POB/ml)	25.37^{c} (18.36)
T_7	*Beauveria basssiana* 1.15WP (2 x 10^8 cfu/gm)	26.11^{c} (19.36)
T_8	Azadirachtin 1500 PPM	27.04^{c} (20.67)
T_9	Control (Untreated)	30.72^{d} (26.10)
S. Em. ±		0.96
C.V. %		7.55

iii) Yield, increase in yield and avoidable loss of pigeon pea in different insecticides

The results on grain yield are presented in Table 4. It can be seen from the data that all the insecticides remained significantly superior over untreated control. The treatment of chlorantraniliprole 18.5 SC (0.006%) had obtained the highest yield of pigeon pea (14.53 q/ha), however, it has remained at par with flubendiamide 480 SC (0.05%) which registered (14.10 q/ha) yield of pigeon pea. Followed by emamectin benzoate 5 SG (0.003%) (12.99 q/ha), lambda-cyhalothrin 5% EC (0.005%) (12.68 q/ha), quinalphos 25 EC (0.05%) (12.50 q/ha), HaNPV [(1 x 10^{10} POB/ml) (250 LE/ha)] (10.43 Q/ha), *Beauveria basssiana* 1.15 WP [(2 x 10^8 cfu/gm) (0.0046%)] (10.21 q/ha) and azadirachtin 1500 ppm (0.00075%) (10.00 q/ha) over untreated control (8.32 q/ha).

Per cent increase in pigeon pea yield over control due to various treatments was worked out based on the grain yield of pigeon pea (Table 4). The results showed that the per cent increase in yield over control was maximum (74.64%) in the treatment of chlorantraniliprole 18.5 SC (0.006%) followed by flubendiamide 480 SC (0.05%) (69.47%) followed by emamectin benzoate 5 SG (0.003%) (56.17%) followed by lambda-cyhalothrin 5% EC (0.005%) (52.40%) followed by quinalphos 25 EC (0.05%) (50.24%) followed by HaNPV [(1 x 10^{10} POB/ml) (250 LE/ha)] (25.40%) and *Beauveria basssiana* 1.15 WP [(2 x 10^8 cfu/gm) (0.0046%)] (22.68%). However, the lowest per cent increase in yield over control was observed in the treatment of azadirachtin 1500 ppm (0.00075%) (20.15%).

Percentage of avoidable loss in yield due to pod borer of pigeon pea after various treatments were worked out based on yield by using the formula suggested by Khosla (1977) [6] and presented in Table 4.

Table 4: Yield, increase in yield and avoidable loss of pigeon pea in different insecticides

Tr. No.	Treatments	Yield (q/ha)	Increase in yield over control (%)	Avoidable loss (%)
T_1	Chlorantraniliprole 18.5 SC	14.53[a]	74.64	0.00
T_2	Lambda-cyhalothrin 5 EC	12.68[bc]	52.40	12.73
T_3	Flubendiamide 480 SC	14.10[ab]	69.47	2.96
T_4	Emamectin-benzoate 5 SG	12.99[bc]	56.17	10.58
T_5	Quinalphos 25 EC	12.50[c]	50.24	13.97
T_6	HaNPV (1 x 10^{10} POB/ml)	10.43[d]	25.40	28.19
T_7	*B. basssiana* 1.15WP (2 x 10^8 cfu/gm)	10.21[d]	22.68	29.75
T_8	Azadirachtin 1500 PPM	10.00[d]	20.15	31.20
T_9	Control (Untreated)	8.32[e]	0.00	42.76
S.Em.±		0.49		
C.V. %		7.20		

It can be seen from the results that the maximum pod yield was obtained in the plots treated with chlorantraniliprole 18.5 SC (0.006%). The minimum avoidable loss (2.96%) in pigeon pea yield was observed in the treatment of flubendiamide 480 SC (0.05%) followed by emamectin benzoate 5 SG (0.003%) (10.58%) followed by lambda-cyhalothrin 5% EC (0.005%) (12.73%) followed by quinalphos 25 EC (0.05%) (13.97%) followed by HaNPV [(1 x 10^{10} POB/ml) (250 LE/ha)] (28.19%) followed by *Beauveria basssiana* 1.15 WP [(2 x 10^8 cfu/gm) (0.0046%)] (29.75%) and azadirachtin 1500 ppm (0.00075%) (31.20%). On the other hand, the highest percentage of avoidable loss in yield of pigeon pea was recorded in untreated plots (42.76%).

iv) Economics of different insecticides in pigeon pea

The Economics of the different treatments against pigeon pea pod borer infesting pigeon pea was worked out considering the prevailing market price of pigeon pea and the cost of insecticidal treatments including labour charges. The total realization, net realization and Protection Cost: Benefit Ratio (PCBR) were also worked out for all the treatments and presented in Table 5.

The total cost of treatment was minimum (550 Rs./ha) in emamectin benzoate 5 SG (0.003%), followed by quinalphos 25 EC (0.05%) (600 Rs./ha) and lambda-cyhalothrin 5% EC (0.005%) (900 Rs./ha), however, HaNPV [(1 x 10^{10} POB/ml) (250 LE/ha)] (2100 Rs./ha) treatment, however chlorantraniliprole 18.5 SC (0.006%) costliest (4000 Rs./ha) treatment.

The gross realization was highest (58120.00 Rs./ha) in chlorantraniliprole 18.5 SC (0.006%) followed by flubendiamide 480 SC (0.05%) (56400.00 Rs./ha), however, it was lowest in untreated control (33266.67 Rs./ha).

The economics of various insecticides (Table 5) revealed that the highest net realization (24853.33 Rs./ha) was obtained in chlorantraniliprole 18.5 SC (0.006%) followed by flubendiamide 480 SC (0.05%) (23133.33 Rs./ha) and emamectin benzoate 5 SG (0.003%) (18706.67 Rs./ha). The lowest net realization over untreated control was observed in the treatment azadirachtin 1500 ppm (0.00075%) (6720.00 Rs./ha). The highest net gain (19813.33 Rs./ha) was obtained in chlorantraniliprole 18.5 SC (0.006%) followed by flubendiamide 480 SC (0.05%) (18893.33 Rs./ha) and emamectin benzoate 5 SG (0.003%) (17116.67 Rs./ha). The remaining insecticidal treatments showed the net gain varied from (3430.00 Rs./ha) to (19813.33 Rs./ha).

The highest Protection Cost: Benefit Ratio (PCBR) was obtained in plots treated with emamectin-benzoate 5 SG (0.003%) (PCBR=1:10.77) and quinalphos 25 EC (0.05%) (PCBR=1:9.20). The Protection Cost: Benefit Ratio (PCBR) was varied from 1:0.98 to 1:10.77 in rest of the insecticidal treatments. The lowest (PCBR 1:0.98) was calculated in the treatment of *Beauveria basssiana* 1.15 WP [(2 x 10^8 cfu/gm) (0.0046%)] (Table 5).

Table 5: Economics of different treatments during kharif 2019-20 in pigeon pea

Tr. No.	Treatments	Dose (ml or g/ 10 lit. of water)	Material required for two Spray (kg or lit./ ha)	Cost of materials (Rs./ha)	Labour Charge (Rs./ha)	Total cost of treatment (Rs./ha)	Yield (Q/ha)	Gross realization (Rs./ha)	Net realization (Rs./ha)	Net gain (Rs./ha)	PCBR
T_1	Chlorantraniliprole 18.5 SC	3	0.3	4000	1040	5040	14.53	58120	24853.33	19813.33	1:3.93
T_2	Lambda-cyhalothrin 5 EC	10	1	900	1040	1940	12.68	50720	17453.33	15513.33	1:8.00
T_3	Flubendiamide 480 SC	2	0.2	3200	1040	4240	14.10	56400	23133.33	18893.33	1:4.46
T_4	Emamectin-benzoate 5 SG	5	0.5	550	1040	1590	12.99	51973.33	18706.67	17116.67	1:10.77
T_5	Quinalphos 25 EC	20	2	600	1040	1640	12.50	50000	16733.33	15093.33	1:9.20
T_6	HaNPV (1 x 10^{10} POB/ml)	10	1	2100	1040	3140	10.43	41733.33	8466.67	5326.667	1:1.70
T_7	*B. basssiana* 1.15WP (2 x 10^8 cfu/gm)	40	4	2780	1040	3820	10.21	40826.67	7560.00	3740	1:0.98
T_8	Azadirachtin 1500 ppm	50	5	2250	1040	3290	10.00	39986.67	6720.00	3430	1:1.04
T_9	Untreated Control	-	-	-	-	-	8.32	33266.67	-	-	-

Price of Pigeon pea: Rs.40/kg; Chlorantraniliprole 18.5 SC: Rs. 13333/lit.; Lambda-cyhalothrin 5 EC: Rs. 900/lit.; Flubendiamide 480 SC: Rs.16000/1.00lit.; Emamectin-benzoate 5 SG: Rs. 1100/kg.; Quinalphos 25 EC: Rs. 300/lit.; HaNPV (1 x 10^{10} POB/ml): Rs.2100/lit.; *B. basssiana* 1.15WP (2 x 10^8 cfu/gm): Rs. 695/kg.; Azadirachtin 1500 ppm: Rs.450/lit.; and Labour charges: Rs. 260 Rs/day/labour.

Conclusion

From present study, it may be concluded that the application of chlorantraniliprole 18.5 SC (0.006%), flubendiamide 480 SC (0.05%) or emamectin benzoate 5 SG (0.003%) should be applied once at 50% flowering stage and 2nd at 15 days after 1st application can better protect the pigeon pea crop and harvested higher yield. Further, the increased in yield over control was found to be higher in plots treated with chlorantraniliprole 18.5 SC (0.006%) followed by flubendiamide 480 SC (0.05%). Hence, the above three chemicals may be suggested for alternate application towards mitigating the losses of *H, armigera* in pigeon pea crop.

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