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Evaluation of Eco-Friendly Approaches for the Management of Pod Borer *Helicoverpa armigera* (Hubner (Lepidoptera:Noctuide) on Pigeonpea [*Cajanus cajan* (L.) millsp.]

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A B S T R A C T

The field experiment was conducted on the topic entitled Evaluation of eco-friendly approaches for the management of Pod borer on pigeonpea [*Cajanus cajan* (L.) millsp.]. The present investigations were conducted at Agriculture Research Farm of Institute of Agriculture Sciences, Banaras Hindu University, Varanasi, (U.P) India during *Kharif* 2018-19 and 2019-20. From the results it was concluded that Chlorantraniliprole 18.5 SC @ 30 g a.i/ha followed by Flubendiamide 480 SC@ 48 g a.i./ha is superior over all the eco-friendly treatments for all the insect pest. For pod borer *Bt. Kurastaki* was second most effective treatment with pod damage 3.66% and 4.67% and grain damage 2.05% and 2.88% in the year 2018-19 and 2019-20.. Therefore, on the basis of above facts regarding evaluation of eco-friendly approaches for the management of major insect pests on pigeonpea experiment, it is concluded that apart from chemical insecticides Azadirchtin and *Bt. Kurastaki* can be very effective for major pigeonpea pests reducing the damage to pods and grains. Azadirchtin also gave higher C: B ratio among all the bio-pesticides which also gave higher benefit compared to farmer's practice. This may affect the socio- economical status of farmer with increased cost: benefit ratio. This information would be helpful to the regional farmers of Varanasi providing a higher income.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp] a very important and widespread used legume. In India it is also called arhar or tur. The detailed scientific classification of the pulse is Magnoliophyta (Division), Magnoliopsida (Class), Fabales (order), Fabaceae (family), Faboideae (subfamily), Phaseoleae (tribe), Cajaninae (subtribe), Cajanus(genus). In India more than 30 species of pigeonpea found in different geographical locations. Pigeonpea is a shorter-day plant having high sensitivity toward longer photoperiod (Gooding, 1962) with maturity period up to 12 months or more. Pigeonpea are hardy plants with erect stem.

Some of the Pigeonpea show determined growth while most show indeterminate growth with height more than 1 meter. Pigeonpea thrive best even in low fertilizer application, little care and with less watering. Pigeonpea has well developed tap root system. The root system mainly formed in the top soil (Natarajan and Willey, 1980). Thus it utilizes the small amount of water and nutrients present in top50cm of soil. *Rhizobium* spp. symbiotically form root nodulation (Chikowo *et al.*, 2004) thus improve soil fertility by fixing atmospherical nitrogen. Some Bio-pesticides like Entomopathogenic bacteria- *Bacillus thuringiensis,* Entomopathogenic fungi like *Beauveria bassiana, Metarhizium anisopliae, Lecanicillium lecanii* and botanicals like NSKE can overcome insect pests problem and hazardous chemical effects (Jeyarani and Karuppuchamy, 2010).These are comparatively safer to environment than chemical insecticides. Environmental pollution, human health hazards, resistance in insect pests, resurgence of pest population can be checked using such eco-friendly insecticides. Due to attack of gram pod borer damage percent varies from 20 to 70. Adult is yellow in colour with brown-blackish spots on the hind wings. Single egg is laid on tender plant parts. Each female can lay upto 300 eggs in its life span. Egg period is 2-4 days. Early instar of caterpillars feed on the tender leaves, the later instar feed on the pods and damage the seeds. Caterpillar enters its head into pods and remaining body lies outside. Full grown caterpillars are 25-40 mm in length with dark colour. Larval period last 20-28 days. It pupates inside soil. The damaged seeds are not suitable for human consumption.

Materials and Methods

The present investigations were conducted at Agriculture Research Farm of Institute of Agriculture Sciences, Banaras Hindu University, Varanasi,(U.P) India during *Kharif* 2018-19 and 2019-20. The long duration pigeonpea variety BAHAR was grown for the experiment. It was carried out in Randomized Block Design (RBD) consisting 7 treatment including control and each treatment were replicated 3 time each. Sowing were done on *24*th July during *Kharif* 2018-19 *27*th July during *Kharif* 2019-20 (standard week)in experimental plots consisting 5 rows measuring 4 x 4 m^2, keeping row to row and plant to plant spacing of 75 and 10 cm, respectively. Harvesting done in 15th standard week. There were seven treatments, among them bio-pesticides applied in four treatments (*Bt. Kurastaki, Beauveria bassiana, Metarhizium anisopliae, Lecanicillium lecanii,)* one is treated with botanical insecticide Azadirachtin 1500 ppm, Chemical insecticides applied in one tratment (Chlorantraniliprole 18.5 SC followed by Flubendiamide 480 SC) and the seventh one is untreated control. The spray solution is prepared by mixing desired quantity of formulations in 750-1000 Ltr. of water per hectare. For spraying purpose ASPEE foot sprayer with cone type nozzle was used. The spraying of insecticides started at the Pod initiation stage of pigeonpea and applied twice at 15 days interval during the crop development. The first spray was done on 9th standard week during both 2018-19 & 2019-20 session while the crop was at 50% pod formation stage. Subsequent spraying was done 15 days after first spraying day.

For the recording of incidence of major pigeonpea insects pests 5 plants were chosen randomly from each experimental plot. The counting of insects start from 50 per cent flowering stage of pigeonpea in weekly interval manner. The incidence of pod fly and pod bug start from 7th standard week upto crop maturity. Major insect pests include Pod fly, *Melanagromyza obtuse* (Malloch), gram pod borer, *Helicoverpa armigera* (Hubner), Tur pod bug, *Clavigralla gibbosa* (Spinola), Legume pod borer, *Maruca vitrata* (Fabricus), Blue butterfly, *Lampides boeticus* (L.) and Plume moth, *Exelastis atomosa* (Walsingham) The number of insect population counted from all three replication of seven treatments.

$$\% \text{ Pod damage} = \frac{\text{Number of damaged pods}}{\text{Total number of pods}} \times 100$$

$$\% \text{ Grain damage} = \frac{\text{Number of damaged grains}}{\text{Total number of grains}} \times 100$$

Results and Discussion

For the spray of insecticides on treatments observation is taken 24 hours before (1DBT), which provided information whether the number of insects count is above ETL or not. The total number of pest population remained in range of 5.60 to 6.40. The data obtained from 1DBT were non-significant in nature for gram pod borer.

The application of insecticides caused a slight reduction in *H.armigera* (Hubner) larvae population after 1 day of treatment (1 DAT). Lowest populations of larvae are observed in case of chemical treatment (Chlorantraniliprole 18.5 SC followed by Flubendiamide 480 SC) that is 4.60 larvae/5 plants followed by *Beauveria bassiana* (5.43 larvae/ 5 plants). On the contrary untreated control plots show maximum number of larvae (6.80 larvae/ 5 plants).

At 3 days of treatment (3 DAT) further decrease in gram pod borer larvae have been observed in all treatments except control plots that is 7.25 larvae/plants. Lowest population of larvae are observed in case of Chemical treatment that is (3.83 larvae/5 plants) followed by *Bt. Kurastaki* (4.56 larvae/ 5 plants). The mean count show that during first spray Chemical control plots show maximum effectiveness with least larvae population (3.95 larvae/5 plants), whereas control plot mean is maximum among all i.e 7.35 larvae/5 plants For the spray of insecticides on treatments observation is taken 24 hours before second spray (1DBT). The larvae population lies in range of 5.05 to 8.40 larvae/5 plants.

After 1 day of treatment (1 DAT) of insecticides further reduction in gram pod borer larvae population is noticed.

Lowest populations of larvae are observed in case of chemical treatment (Chlorantraniliprole 18.5 SC followed by Flubendiamide 480 SC) that is 3.13 larvae/5 plants followed by *Bt. Kurastaki* (4.67 larvae/ 5 plants). Whereas untreated control plots show increase in gram pod borer having maximum number of larvae(8.75 larvae/ 5 plants).

Table.1 Details of the insecticidal treatments applied in experimental trial.

Treatments	Name of treatments	Dose
T1	*Bacillus thuringiensis kurastaki*	1.0 g/l
T2	*Beauveria bassiana*	5.0 g/l
T3	*Metarhizium anisopliae*	5.0 g/l
T4	*Lecanicillium lecanii*	5.0 g/l
T5	Azadirachtin 1500 ppm	5.0 ml/l
T6	Chlorantraniliprole 18.5 SC followed by Flubendiamide 480 SC	30 g a.i/ha + 48 gai/ha
T7	Control (Untreated)	-

Table.2 Effect of eco-friendly insecticides against gram pod borer (*H.armigera*) on pigeonpea during *Kharif* 2018-19.

Treatment	Dose	No. of Larvae per 5 plants*												Pooled mean
		1st Spray						2nd Spray						
		1DBT	1DAT	3DAT	7DAT	10 DAT	Mean	1DBT	1DAT	3 DAT	7 DAT	10 DAT	Mean	
Bt. Kurastaki	1.0 g/l	6.40 (2.72)	5.67 (2.58)	4.56 (2.35)	4.20 (2.28)	4.83 (2.41)	4.81 (2.40)	5.43 (2.53)	4.67 (2.38)	4.07 (2.25)	3.47 (2.11)	2.79 (1.94)	3.75 (2.17)	4.28 (2.28)
Beauveria bassiana	5.0 g/l	5.60 (2.56)	5.43 (2.53)	5.27 (2.50)	4.65 (2.37)	4.90 (2.42)	5.06 (2.45)	5.96 (2.63)	5.14 (2.47)	4.76 (2.39)	4.23 (2.28)	3.67 (2.16)	4.45 (2.32)	4.75 (2.38)
Metarhizium anisopliae	5.0 g/l	7.05 (2.82)	6.07 (2.65)	5.43 (2.53)	5.03 (2.45)	4.95 (2.43)	5.37 (2.51)	6.13 (2.67)	5.33 (2.51)	5.07 (2.46)	4.76 (2.39)	4.40 (2.32)	4.89 (2.42)	5.13 (2.46)
Lecanicillium lecanii	5.0 g/l	7.05 (2.77)	6.27 (2.69)	5.75 (2.59)	5.90 (2.62)	5.33 (2.51)	5.76 (2.60)	6.97 (2.82)	6.23 (2.68)	5.96 (2.63)	5.40 (2.53)	5.11 (2.47)	5.67 (2.57)	5.71 (2.58)
Azadirachtin 1500 ppm	5.0 ml/l	5.93 (2.63)	5.53 (2.55)	4.80 (2.40)	4.73 (2.39)	4.97 (2.44)	5.00 (2.44)	5.87 (2.61)	4.80 (2.40)	4.33 (2.30)	4.13 (2.26)	3.06 (2.01)	4.08 (2.24)	4.54 (2.34)
Chlorantraniliprole 18.5 SC +	@ 30 ga.i/ha+	6.00 (2.64)	4.60 (2.36)	3.83 (2.19)	3.08 (2.02)	4.30 (2.30)	3.95 (2.21)	5.05 (2.45)	4.40 (2.32)	3.13 (2.03)	2.44 (1.85)	1.07 (1.43)	2.76 (1.90)	3.36 (2.05)
Flubendiamide 480 SC	48 ga.i/ha													
Control (Untreated)	-	6.25 (2.69)	6.80 (2.79)	7.25 (2.87)	7.40 (2.89)	7.95 (2.99)	7.35 (2.88)	8.40 (3.06)	8.75 (3.12)	7.80 (2.96)	7.35 (2.88)	6.9 (2.80)	7.7 (2.94)	7.52 (2.91)
CD at p =0.05%	-	N.S	0.32	0.61	0.53	0.48	0.48	1.03	0.89	0.75	0.84	0.61	0.77	0.62
SE(m)±	-	0.43	0.10	0.19	0.53	0.15	0.24	0.33	0.28	0.24	0.27	0.19	0.24	0.24

*Figures in Parenthesis are subjected to square root ($\sqrt{x} + \mathbf{0.}$) transformation.

Table.3 Effect of eco-friendly insecticides against gram pod borer (*H.armigera*) on pigeonpea during *Kharif* 2019-20.

Treatment	Dose	No. of Larvae per 5 plants*												
					1st Spray						2nd Spray			Pooled mean
		1 DBT	1 DAT	3 DAT	7 DAT	10 DAT	Mean	1 DBT	1 DAT	3 DAT	7 DAT	10 DAT	Mean	
Bt. kurastaki	1.0 g/l	6.96	6.50	6.29	4.45	4.66	5.47	4.96	4.26	3.77	3.40	3.68	3.77	4.62
		(2.81)	(2.73)	(2.70)	(2.33)	(2.37)	(2.53)	(2.44)	(2.29)	(2.18)	(2.09)	(2.16)	(2.18)	(2.35)
Beauveria bassiana	5.0 g/l	7.15	6.87	6.40	6.15	5.83	6.31	6.40	6.15	5.40	4.97	4.04	5.14	5.72
		(2.85)	(2.80)	(2.72)	(2.67)	(2.61)	(2.70)	(2.72)	(2.67)	(2.52)	(2.44)	(2.24)	(2.46)	(2.58)
Metarhizium anisopliae	5.0 g/l	6.93	6.60	6.53	6.33	6.48	6.48	6.60	5.96	5.66	5.03	4.77	5.35	5.91
		(2.81)	(2.75)	(2.74)	(2.70)	(2.73)	(2.73)	(2.75)	(2.63)	(2.58)	(2.45)	(2.39)	(2.51)	(2.62)
Lecanicillium lecanii	5.0 g/l	7.40	7.13	6.87	6.50	6.77	6.81	6.83	6.13	5.87	5.00	4.73	5.43	6.12
		(2.89)	(2.85)	(2.80)	(2.73)	(2.95)	(2.83)	(2.79)	(2.67)	(2.62)	(2.44)	(2.39)	(2.53)	(2.68)
Azadirachtin 1500 ppm	5.0	6.85	6.77	6.40	5.13	5.07	5.84	5.46	5.07	4.33	4.00	3.87	4.31	5.07
	ml/l	(2.80)	(2.78)	(2.71)	(2.47)	(2.46)	(2.60)	(2.54)	(2.46)	(2.30)	(2.23)	(2.20)	(2.29)	(2.44)
Chlorantraniliprole 18.5 SC +	@ 30 g	7.63	6.05	5.40	4.16	4.25	4.96	4.33	3.80	2.73	2.02	0.88	2.35	3.65
	a.i/ha+	(2.93)	(2.65)	(2.52)	(2.27)	(2.29)	(2.43)	(2.30)	(2.18)	(1.93)	(1.73)	(1.37)	(1.80)	(2.11)
Flubendiamide 480 SC	48 g													
	a.i/ha													
Control (Untreated)	-	7.35	7.63	7.96	8.23	8.41	8.05	8.86	9.15	9.53	9.35	8.40	9.10	8.57
		(2.88)	(2.93)	(2.93)	(3.03)	(3.06)	(2.98)	(3.14)	(3.18)	(3.24)	(3.18)	(3.06)	(3.16)	(3.07)
CD at p =0.05%	-	N.S	0.70	0.55	0.87	1.20	0.83	0.62	0.99	0.58	0.61	0.50	0.67	0.75
SE(m)±	-	0.32	0.22	0.17	0.28	0.38	0.26	0.19	0.32	0.18	0.19	0.16	0.21	0.23

*Figures in Parenthesis are subjected to square root ($\sqrt{x}$ + **0**.) transformation.

Table.4 Cost-Benefit analysis of insecticidal treatments against the majot insect pests in Pigeonpea during 2018-19.

Treatment	Dose	Pod borer		Grain yield (kg/ha)	Incremental yield over control (kg/ha)	Value of incremental	Total Cost of treatment (Rs/ha)	Profit due to treatment (Rs)	Cost-benefit ratio
		% Pod damage	% Grain damage						
Bt. kurastaki	1.0 g/l	3.66	2.05	903.88	74.16	4041.72	1220	2821.72	1:2. 31
		(11.01)	(8.06)						
Beauveria bassiana	5.0 g/l	5.35	3.28	926.50	96.78	5274.51	1300	3974.51	1: 3.05
		(13.14)	(10.37)						
Metarhizium anisopliae	5.0 g/l	5.66	3.44	912.56	82.84	4514.78	1475	3039.78	1: 2.06
		(13.72)	(10.66)						
Lecanicillium lecanii	5.0 g/l	5.30	3.23	917.33	87.61	4774.74	1275	3499.74	1:2.74
		(13.26)	(10.24)						
Azadirachtin 1500 ppm	5.0 ml/l	5.30	2.30	1003.72	174.00	9483.00	2300	7183.00	1: 3.12
		(13.26)	(8.70)						
Chlorantraniliprole 18.5 SC + Flubendiamide 480 SC	@ 30 g a.i/ha + 48 g a.i/ha	2.66 (8.91)	1.93 (7.89)	1185.10	355.38	19,368.21	2955	16413.21	1:5.55
Control (Untreated)	-	8.66	5.01	829	-	-	-	-	-
		(17.11)	(12.92)						
CD at p = 0.05%	-	3.80	2.01						
SE(m)±	-	1.22	0.64						

Price of *Bt. Kurastaki* Rs.640/kg, Price of *Beauveria bassiana* Rs.160/kg, Price of *Metarhizium anisopliae* Rs.230/kg, Price of *Lecanicillium lecanii* Rs.150/kg, Price of Azadirachtin 1500 ppmRs.560/L, Price of Chlorantraniliprole 18.5 SC Rs.13,100/L, Price of Flubendiamide 480 SC Rs. 850/L, No. of unskilled labour needed per spray-1,Wage of labour per day-Rs. 450, No. of spray- 2, Market price of Pigeonpea Rs. 54/kg.

Table.5 Cost-Benefit analysis of insecticidal treatments against the majot insect pests in Pigeonpea during 2019-20.

Treatment	Dose	Pod borer		Grain yield (kg/ha)	Incremental yield over control (kg/ha)	Value of incremental	Total Cost of treatment (Rs/ha)	Profit due to treatment (Rs)	Cost-benefit ratio
		% Pod damage	% Grain damage						
Bt. Kurastaki	1.0 g/l	4.67	2.88	895.32	75.91	4099.20	1220	2879.20	1: 2.36
		(12.45)	(9.71)						
Beauveria bassiana	5.0 g/l	6.66	4.49	934.00	107.38	5798.70	1300	4498.70	1: 3.46
		(14.89)	(12.22)						
Metarhizium anisopliae	5.0 g/l	7.66	4.56	910.50	90.6	4937.70	1475	3462.70	1: 2.34
		(16.01)	(12.27)						
Lecanicillium lecanii	5.0 g/l	6.00	4.18	903.76	84.36	4597.62	1275	3322.62	1: 2.60
		(14.04)	(11.72)						
Azadirachtin 1500 ppm	5.0 ml/l	5.35	3.28	1013.22	193.82	10563.19	2300	8263.19	1: 3.59
		(13.26)	(10.44)						
Chlorantraniliprole 18.5 SC + Flubendiamide 480 SC	@ 30 g a.i/ha + 48 g a.i/ha	3.33 (10.39)	2.26 (8.51)	1180.60 819.40	361.2 -	19685.40 -	2955 -	16730.40 -	1: 5.66 -
Control (Untreated)	-	9.34	6.28						
		(17.75)	(14.50)						
CD at p = 0.05%	-	2.67	1.28						
SE(m)±	-	0.85	0.41						

Price of *Bt. Kurastaki* Rs.640/kg, Price of *Beauveria bassiana* Rs.160/kg, Price of *Metarhizium anisopliae*Rs.230/kg, Price of *Lecanicillium lecanii* Rs.150/kg, Price of Azadirachtin 1500 ppmRs.560/L, Price of Chlorantraniliprole 18.5 SC Rs.13,100/L, Price of Flubendiamide 480 SC Rs. 850/L, No. of unskilled labour needed per spray-1,Wage of labour per day-Rs. 450, No. of spray- 2, Market price of Pigeonpea Rs. 54/kg.

At 3 days of treatment (3 DAT) further decrease in gram pod borer larvae have been observed in all treatments except control plots that is 7.80 larvae/plants. Lowest population of larvae have been observed in case of Chemical treatment that is (3.13 larvae/5 plants) followed by *Bt. Kurastaki* (4.07 larvae/ 5 plants). At 7 DAT lowest population of larvae are recorded in case of Chemical treatment (Chlorantraniliprole 18.5 SC followed by Flubendiamide 480 SC) i.e 2.44 larvae/5 plants) followed by *Bt. Kurastaki* (3.47 larvae/ 5 plants). Maximum number of gram pod borer larvae count can be seen in Control plots i.e.7.35 larvae/5 plants. At 10 days of treatment (10 DAT) reduction in gram pod borer larvae population in maximum treatments except control plots. Lowest population of larvae are observed in case of chemical treatment1.07 larvae/5 plants followed by *Bt. Kurastaki* (2.79 larvae/ 5 plants).The larvae population in control plot is maximum i.e 6.90 larvae/ 5 plants).

The mean count of second spray data show that Chemical control plots show maximum effectiveness with least larvae population (2.76 larvae/5 plants), whereas control plot mean is maximum among all i.e (7.7 larvae/5 plants. The pooled mean data shows the decreasing order of effectiveness of insecticides in the following sequences.

Chemicals {Chlorantraniliprole 18.5 SC followed by Flubendiamide 480 SC} (3.36 larvae/5 plants)>*Bt. Kurastaki* (4.28 larvae/5 plants) >Azadirachtin 1500 ppm(4.54 larvae/5 plants) >*Beauveria bassiana* (4.75 larvae/5 plants) >*Metarhizium anisopliae*(5.13larvae/5 plants) >*Lecanicillium lecanii*(5.71 larvae/5 plants) >Untreated control(7.52 larvae/5 plants)

For the entire pod borer pest the chemical treatment (Chlorantraniliprole 18.5 SC followed by Flubendiamide 480 SC) is found superior over all the eco-friendly insecticides. *Bt. Kurastaki* was the second most effective treatment for all the Lepidoptera borer Gram pod borer population in all the treatments expressed different results in response to different insecticides.

During experiment it was found that after 1st& 2nd spray chemical treatment (Chlorantraniliprole 18.5 SC followed by Flubendiamide 480 SC) reduce population of *H. armigera* (Hubner) larvae population significantly. The pooled mean data revealed that the larvae count were recorded least in chemical treatment having 3.36 larvae/5 plants and 3.65 larvae/5 plants plants for year 2018-19 and 2019-20 respectively.

Among all the treatments the second most effective insecticide was *Bt. Kurastaki* with mean count 4.28 larvae/5 plants(Year 2018-19) and 4.62 larvae/5 plants (Year 2019-20). *Lecanicillium lecanii* was least effective insecticides among all the eco-friendly insecticides with 5.71 larvae/5 plants& 6.12 larvae/5 plants in the year 2018-19 and 2019-20 respectively. The present finding of Taggar *et al.*,(2018) stated that in multi location research performed in 2016 to 1018 on pod borer *Helicoverpa armigera* (Hubner) gave similar results. The chemical chlorantraniliprole 18.5 SC followed by flubendiamide 480 SC caused significant reduction in larvae population. Also the result partially supports study of Sreekanth *et al.*,(2013) who stated that *Helicoverpa l*arvae per plant were lowest in plots treated with chlorantraniliprole 20 SC (0.43 larvae/5 plants), flubendiamide 480 SC (0.59 larvae/5 plants) as compared to control plot (4.17 larvae/5 plants). The Chlorantraniliprole 18.5 SC @ 30 g a.i/ha followed by Flubendiamide 480 SC@ 48 g a.i./ha is superior over all the eco-friendly treatments for all the insect pest. For Pod fly and pod bugs Azadirachtin 1500 ppm second most effective treatment but for pod borer *Bt. Kurastaki* found significantly effective.

The study on eco-friendly approaches can be a medium to draw conclusion for effective control of major insect pest of pigeonpea. Therefore, on the basis of above facts regarding evaluation of eco-friendly approaches for the management of major insect pests on pigeonpea experiment, it is concluded that apart from chemical insecticides Azadirachtin and Bt. Kurastaki can be very effective for major pigeonpea pests reducing the damage to pods and grains. Azadirachtin also gave higher C: B ratio among all the bio-pesticides which also gave higher benefit compared to farmer's practice.

This may affect the socio- economical status of farmer with increased cost: benefit ratio. This information would be helpful to the regional farmers of Varanasi providing a higher income.

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