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Bioefficacy of various insecticides against *Helicoverpa armigera* (Hubner) on pigeon pea (*Cajanas cajan*) (L) Millsp.

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Abstract
The field experiment was conducted to assess the bioefficacy of various insecticides against *Helicoverpa armigera* on pigeon pea (*Cajanas cajan* (L) Millsp.) with eight treatments including an untreated control. In treatments *viz.,* Quinalphos 25 EC, Emamectin benzoate 5 SG, Indoxacarb 14.5 SC, Chlorantraniliprole 18.5 SC, Chlorpyriphos 20 EC, Flubendamide 39.35 SC, Lambda cyhalothrin 5 EC. These treatments replicated thrice in randomized block design. The performance of each insecticide treatment was judged on the basis of larval incidence, pod damage, grain damage and grain yield. Considering the effectiveness of various insecticides in reducing the larval population, the treatment with chlorantraniliprole 18.5 SC was emerged as the most promising treatment for the management of *Helicoverpa armigera* (Hubner). The next promising treatment reducing *H. armigera* larval population was flubendiamide 39.35 SC which was followed by the treatment with indoxacarb 14.5 SC. The treatment with chlorantrniliprole 18.5 SC was superior in reducing collective pod and grain damage. The maximum grain yield was obtained from the plots treated with chlorantrniliprole 18.5 SC (17.18 q /ha).

Keywords: pigeon pea, *Helicoverpa armigera*, pod damage, grain damage, grain yield

Introduction
Pulses constitute an integral part of Indian agriculture because of their vital role in enriching the human diet as well as soil fertility. Being the cheapest source of protein, pulses form an inseparable part of the Indian diet. Besides their higher nutritional value, pulse crops have a unique characteristic of maintaining and restoring soil fertility through biological nitrogen fixation and thus play a vital role in sustainable agriculture (Asthana, 1998) [1]. India ranks first in area with 4.43 Mha and production 4.25 Million Tonnes. The Area under pigeon pea crop in Maharastra was 1.23 Million ha with annual production of 1.07 Million Tonnes. Although the area under pigeon pea is increasing but yield is not satisfactory. This is due to several limiting factor and one of them is infestation of pests (Anonymous, 2018) [2]. More than 300 insect species belonging to 8 orders and 61 families have been found to infest pigeon pea starting from seedling stage and continues till harvesting and even during the storage condition (Keval *et al*., 2010) [3]. However, about 60% damage is solely caused by the pod borer complex (Wadasker *et al*., 2013) [4] According to Lal *et al*. (1992) [5] pod borers caused 60 to 90 percent loss in the grain yield under favorable conditions and damage of seed by pod fly ranged from 14.3 to 46.6 percent. To control these pests, farmers solely rely upon insecticides as the first line of defense to get immediate action. Abuse of insecticides has aggravated the pest problem leading to resurgence, outbreak of secondary pests and development of insecticidal resistance. So that selection of ecofriendly insecticides which is safe to natural enemies and also should not leave toxic residues is essential for pest management programme.

Materials and Methods
The present experiment was conducted during *khariff* season of 2020 at AICRP on pigeon pea, Pulses Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri. In field plots the seed of pigeon pea were sown by following the recommended agronomic practices.

Details of experiment
Design: Randomized Block Design
Replications: Three

Treatments: Eight
Variety: ICPL-87
Plot size: 4.50 x 3.60 m2
Spacing: 90 x 60 cm
Fertilizer dose: 25:50:25, NPK kg/ha.
Method of sowing: Dibbling
Seed rate: 12 kg/ha.
Date of sowing: 23 July 2019.

Method of recording observations
The efficacy of insecticides was evaluated by selecting five plants randomly from each treated plot for recording observations on number of *H. armigera* larvae before each application and at 3, 7 and 14 days after the application of insecticide treatment. Five plants selected earlier randomly from each plot were observed for pod damage at the time of harvesting. Number of damaged pods and healthy pods were counted. The pods were opened and examined for grain damage. From that percent pod damage and grain damage were calculated by following using formula.

$$\text{Percent pod damage} = \frac{\text{Infected pods}}{\text{Total no. of pods}} \text{ X } 100$$

$$\text{Percent grain damage} = \frac{\text{No. of damaged grain}}{\text{No. of healthy grains 3}} \text{ X } 100$$

Statistical analysis
The larval numbers were transformed into $\sqrt{n + 0.5}$ for further statistical analysis. The data on percent damaged pods and grains were transformed into arc sin values to reduce the variation in different treatments and then subjected to statistical analysis. The significance of treatments was assessed by determining critical difference (CD.) at 5% level of significance.

Results and Discussion
Bioefficacy against *H. armigera*
After first spray
The effect of various treatments under investigation on survival of larvae of *H. armigera* after first spray is illustrated in Table 1. The average number of *H. armigera* larvae per plant prior to insecticidal treatments ranged from 1.87 to 2.67 larvae/plant and differences among the treatments were non-significant. The data recorded 3 days after spraying revealed that, all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.53 to 0.93 in the various insecticidal treatments as against 2.3 larvae/plant in untreated control. The treatment with chlorantraniliprole 18.5% SC was found to be most effective treatment and recorded 0.53 larvae per plant and was significantly superior over rest of the treatments. It was followed by the treatment with flubendiamide 39.35% SC (0.63 larvae/plant) and indoxacarb 14.5% SC (0.67 larvae/plant) which were at par with each other. The next best treatment were emamectin benzoate 5% SG (0.73 larvae/plant) and lambda cyhalothrin 5% EC (0.80 larvae/plant). The observations on no of *H. armigera* larvae/plant recorded 7 days after spraying showed that the average number of larvae ranged from 0.33 to 0.80 larvae/plant in the insecticidal treatments as against 2.27 larvae/plant in untreated control. The treatment with T4 (0.33 larvae/plant was found significantly superior over all the treatment in reducing the *H. armigera* larval population expect the treatment with T6 (0.53 larvae/plant)which were at par with each other. In order of efficacy the next best treatment were T3, T4, T7, with 0.60, 0.63, and 0.67 larvae/plant, respectively. At 14 days after first spraying *H. armigera* recorded larval population varied from 0.47 to 1.07 larvae/plant in the insecticidal treatments as against 2.53 larvae/plant in untreated control. The treatment with chlorantrasniliprole 18.5% SC was significantly superior over all the treatments which recorded 0.47 larvae/plant and was at par with T6 with 0.60 larvae/plant. The next promising treatments were by indoxacarb 14.5% SC (0.73 larvae/plant) followed by T2 (0.80 larvae/plant), T7 and T5 which were also at par with each other.

After second spray
The effect of various insecticidal treatments on survival of *H. armigera* after second spray was presented in Table 1. From the results it was revealed that at 3 days after spray all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.33 to 0.87 in the insecticidal treatments as against 2.67 in untreated control. The treatment with chlorantraniliprole 18.5% SC was most effective treatment and recorded 0.33 larvae per plant and was significantly superior over rest of the treatments except the treatment T6 (0.53 larvae/plant) which were at par with each other. The next promising treatments indoxacarb 14.5% SC (0.60) followed by the treatment with emamectin benzoate 5% SG (0.67 larvae/plant) and T7 (0.73 larvae/plant) which were at par with each other. At 7 days after spray showed that the average number of *H. armigrea* larval population ranged from 0.27 to 0.67 larva/plant in different insecticidal treatments as against 2.87 larvae/plant in untreated control. The treatment with chlorantraniliprole 18.5% SC was significantly superior over all the treatments which recorded 0.27 larvae/plant. In the order of effectiveness the next best treatment were flubendiamide 39.35% SC (0.40 larvae/plant), indoxacarb 14.5% SC (0.47 larvae/plant) and emamectin benzoate 5% SG (0.53 larvae/plant). The observations on *H. armigera* larval population at 14 days after spray showed that the average number of larval population ranged from 0.40 to 0.87 larvae/plant in various insecticidal treatments as against 3.07 larvae/plant in untreated control. From the result it was revealed that the treatment with T4 was found to be significantly superior over all the treatment with least *H. armigera* larval population of 0.40 larvae/plant. It was followed by the treatment with T6 with 0.58 larvae/plant and were at par with each other. The next best treatment were T3 (0.60 larvae/plant), T2 (0.63 larvae/plant) and T5 (0.80 larvae/plant). Untreated control recorded maximum *H. armigera* larval population (3.07 larvae/plant).

After third spray
The effect of various treatments on larval population of *H. armigera* after third spray illustrated in Table 1. The data recorded 3 days after spray revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.20 to 0.67 larvae/plant in the insecticidal treatments as against 3.13 larvae/plant in untreated control. The treatment with chlorantraniliprole 18.5% SC was most effective treatment and recorded 0.20 larvae per plant which was significantly superior over rest of the treatments expect the

treatment with T6 (0.47 larvae/plant) which were at par with each other The next effective treatments were indoxacarb 14.5% SC (0.53 larvae/plant), emamectin benzoate 5% SG (0.58 larvae/plant), lambda cyhalothrin 5% EC (0.60 larvae/plant), Chlorpyriphos 20% EC (0.63 larvae/plant) and Quinolphos 25% EC (0.67 larvae/plant) which were at par with each other. The data recorded at 7 days after spray revealed that all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.13 to 0.63 larvae/plant in the insecticidal treatments as against 3.27 larvae/plant in untreated control. The treatment with chlorantraniliprole 18.5% SC was most effective treatment and recorded 0.13 larvae per plant which was followed by the treatment with T6 (0.40 larvae/plant) and were at par with each other. The next promising treatments were indoxacarb 14.5% SC (0.47 larvae/plant), Emamectin benzoate 5% SG (0.47 larvae/plant), lambda cyhalothrin 5% EC (0.53 larvae/plant) and chlorpyriphos 20% SC (0.60 larvae/plant). From the data it was noticed that at 14 DAS all the insecticidal treatments were significantly superior over untreated control. The average number of *H. armigera* larvae/plant ranged from 0.33 to 0.80 in the insecticidal treatments as against 3.33 larvae/ plant in untreated control. The treatment with chlorantraniliprole 18.5% SC was most effective treatment with 0.33 larvae per plant and was significantly superior over rest of the treatments except the treatment T6 (0.53 larvae/plant) and were at par with each other. The next best treatments in effectiveness were indoxacarb 14.5% SC (0.58 larvae/Plant), emamectin benzoate 5% SG (0.63 larvae/plant) and Lambda cyhalothrin 5.

Table 1: Bioefficacy of various insecticides against *Helicoverpa armigera* on pigeon pea

Tr. No.	Treatments	Dose ml or gm/Lit	No. of *H. armigera* larvae/plant									
			Pre-count	After 1st spray			After 2nd spray			After 3rd spray		
				3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS
T1	Quinalphos 25 EC	2.00 ml	2.40 (1.70)	0.93 (1.20)	0.80 (1.14)	1.07 (1.25)	0.87 (1.17)	0.67 (1.08)	0.87 (1.17)	0.67 (1.08)	0.63 (1.06)	0.80 (1.14)
T2	Emamectin benzoate 5 SG	0.40 gm	2.20 (1.64)	0.73 (1.11)	0.63 (1.06)	0.80 (1.14)	0.67 (1.08)	0.53 (1.06)	0.63 (1.06)	0.58 (1.04)	0.47 (0.98)	0.63 (1.06)
T3	Indoxacarb 14.5 SC	0.70 ml	1.87 (1.54)	0.67 (1.08)	0.60 (1.05)	0.73 (1.11)	0.60 (1.05)	0.47 (0.98)	0.60 (1.05)	0.53 (1.01)	0.47 (0.98)	0.58 (1.04)
T4	Chlorantraniliprole 18 SC	0.30 ml	2.13 (1.62)	0.53 (1.01)	0.33 (0.91)	0.47 (0.98)	0.33 (0.91)	0.27 (0.88)	0.40 (0.95)	0.20 (0.83)	0.13 (0.79)	0.33 (0.91)
T5	Chlorpyriphos 20 SC	2.00 ml	2.67 (1.78)	0.87 (1.17)	0.73 (1.29)	0.93 (1.20)	0.80 (1.14)	0.63 (1.06)	0.80 (1.14)	0.63 (1.06)	0.60 (1.05)	0.73 (1.11)
T6	Flubendiamide 39.35 SC	0.25 ml	2.20 (1.64)	0.63 (1.06)	0.53 (1.01)	0.67 (1.08)	0.53 (1.01)	0.40 (0.95)	0.58 (1.04)	0.47 (0.98)	0.40 (0.95)	0.53 (1.01)
T7	Lambda cyhalothrin 5 EC	1.00 ml	2.33 (1.68)	0.80 (1.14)	0.67 (1.08)	0.87 (1.17)	0.73 (1.11)	0.58 (1.04)	0.67 (1.08)	0.60 (1.05)	0.53 (1.01)	0.67 (1.08)
T8	Untreated control		1.87 (1.54)	2.13 (1.62)	2.27 (1.66)	2.53 (1.74)	2.67 (1.78)	2.87 (1.84)	3.07 (1.89)	3.13 (1.28)	3.27 (1.94)	3.33 (1.95)
SE ±			0.08	0.05	0.06	0.06	0.06	0.05	0.04	0.07	0.07	0.06
CD at 5%			N.S.	0.15	0.18	0.18	0.19	0.17	0.12	0.21	0.23	0.18
CV%			12.26	12.17	13.11	12.66	13.43	12.54	12.07	13.78	13.26	12.87

Figure in the parenthesis are √n + 0.5 transformed value

Table 2: Effect of insecticidal treatments on pod damage, grain damage and grain yield of pigeon pea

Tr. No.	Treatment	Dose ml or gm/Lit	*H. armigera*		
			Percent pod damage	Percent grain damage	Grain yield (q/ha)
T1	Quinalphos 25 EC	2.00 ml	9.21 (17.64)	14.49 (22.36)	13.45
T2	Emamectin benzoate 5 SG	0.40 gm	6.64 (14.87)	9.24 (17.69)	14.92
T3	Indoxacarb 14.5 SC	0.70 ml	6.12 (14.26)	8.94 (17.36)	15.55
T4	Chlorantraniliprole 18 SC	0.30 ml	3.64 (10.94)	6.37 (14.57)	17.18
T5	Chlorpyriphos 20 SC	2.00 ml	8.17 (16.56)	12.21 (20.43)	14.07
T6	Flubendiamide 39.35 SC	0.25 ml	4.82 (12.59)	8.02 (16.40)	16.19
T7	Lambda cyhalothrin 5 EC	1.00 ml	7.80 (1.16)	10.87 (19.22)	14.57
T8	Untreated control	----	22.64 (28.40)	24.64 (29.75)	9.63
S.E. ±			0.75	0.98	0.76
C.D. at 5%			2.28	2.95	2.28
C.V. (%)			11.67	13.18	1427

Figure in the parenthesis are arcsine transformed value for percentage damage. % EC (0.67 larvae/plant) and were at par with each other.

Pod damage inflicted by *H. armigera*

The data presented in Table 2 indicated that, all the treatments with insecticide were significantly superior over the untreated control. Maximum pod damage of 22.64% due to *H. armigera* was recorded in untreated control plot whereas, percent pod damage in various insecticide treated plot varied from 3.64 to 9.21%. Amongst the treatments, chlorantraniliprole 18.5% SC recorded least pod damage of 3.64 percent and remain superior over all the treatments. The next promising treatments were flubendiamide 39.35% SC (4.82%) followed by indoxacarb 14.5% SC (6.12%) and emamectin benzoate 5% SG (6.64%) which were at par with each other.

Grain damage influenced by *H. armigera*

The data illustrated in Table 2 on grain damage caused by *H. armigera* indicated that the damage due to the *H. armigera* was 24.64 percent in untreated plot as against 6.37 to 14.49 percent in treated plots. All the insecticidal treatments were significantly superior over untreated control in reducing the percent the grain damage. The treatment with chlorantraniliprol 18.5% SC recorded lowest grain damage of 6.37% followed by flubendiamide 39.35% SC (8.02%), indoxacarb 14.5% SC (8.94%), emamectin benzoate 5% SG (9.24%).

Effect of different treatments on grain yield of pigeon pea

Maximum pigeon pea grain yield of 17.18 q/ha was harvested from the treatment with T4 and it was significantly superior over rest of the treatment. Next promising treatment were T6, T3, and T2 with 16.19, 15.55 and 14.92 q/ha grain yield respectively. It was followed by the treatment with lambda cyhalothrin 5% EC (14.57 q/ha), chlorpyriphos 20% EC (14.07 q/ha), quinolphos 25% EC (13.45q/ha). Untreated plot registered lowest yield (9.63 q/ha) of pigeonpea. (Table 2).

On the basis of influence of treatment on yield chlorantraniliprol 18.5% SC is best treatment which is followed by flubendiamide 39.35% SC. During the present investigation chlorantraniliprole 18.5% SC were found most effective with significantly high reduction of pod and grain damage collectively due to *H. armigera*. The present findings in respect of chlorantraniliprole 18.5% SC are in agreement with those of Dadas *et al.* (2019a) [6]. The performance of spinosad has been well documented by earlier workers like Rani *et al.* (2018) [7] and Patel and Patel (2013) [8]. Similarly, Sreekanth *et al.* (2014) [9] obtained effective control of pod borers through application of chlorantraniliprole 18.5% in pigeon pea. The findings of these workers are confirmative with present findings.

The next treatment in order of efficacy against collective pod and grain damage flubendiamide 39.35% SC. This result is in conformity with the findings of Priyadarshini *et al*. (2017) [10] and Wadaskar *et al.* (2013) [4] proved to be the best treatment in reducing the pod damage. Similarly, Deshmukh *et al.* (2010) [11] determined that flubendiamide 0.007 percent in pigeonpea was found the most effective in reducing the *H. armigera* population and pod damage and showed the highest yield of 1850 Kg ha-1 and cost benefit ratio of 1:6.10. Similar with Tohinshi *et al* (2010) [12]. The next best treatment in order of effectiveness was Indoxacarb 14.5% SE. These results corroborate the findings of Meena *et al*. (2018) [13] which is similar with Patange and Chiranjeevi (2013) [14] and Dinesh *et al*. (2017) [15] who reported that indoxacarb 14.5% SC provided good control against pod borer complex of pigeon pea.

The next promising treatment was emamectin benzoate 5% SG effective in reducing larval population and pod and grain damage. These results corroborate the findings of Chandra and Singh (2014) [16] and Sonune and Bhamare (2018) [17]. According Dadas *et al*. (2019) [6], application of chlorantraniliprole 18.5% SC 50% flowering and podding stage of 15 days interval resulted in higher yield of pigeon pea (8.79 qt/ha). Similarly, Sreekanth *et al*. (2014) [9] also observed effective control of pod borer with highest yield of 886.1kg /ha when chlorantraniliprole 18.5% SC 50% was applied thrice, commensing from 50% flowering stage. Also, higher yield of pigeonpea by using chlorantraniliprole 18.5% SC (686.1 kg/ha) was reported by Khorasiya *et al*. (2004) [18].

Conclusion

The treatment with chlorantraniliprole 18.5% SC and flubendiamide 39.35% SC were found to be most effective treatments against pod borer complex of pigeon pea and give best control coupled with maximum yield.The next best treatment were indoxacarb 14.5% SE and emamectin benzoate 5% SG

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