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Evaluate the bio efficacy of different insecticides against pod borer *Helicoverpa armigera* in Pigeonpea

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Abstract
Investigation on "Evaluate the bio efficacy of different insecticides against pod borer *Helicoverpa armigera* in Pigeonpea" was conducted during June 2016 to February 2017, at the Research cum Instructional farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (CG). Management of *H. armigera* by sequential insecticidal treatments, Treatment 5 with sequential application of Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha maintained its lethal effect with least percent pod damage (15.58%), grain damage (6.41%) showed highest grain yield (1302.08 kg/ha) and net profit over untreated control (Rs.15511.83) which was at par with treatment 6 Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha>Acetamiprid 20 SP @ 20g a.i./ha [(18.23%), (7.21%), (1192.01 kg/ha) and (Rs.11303.30) respectively]. In the untreated control the yield obtain was 856.42 kg /ha which was lowest of all the insecticidal treatments.

Keywords: bio efficacy, different insecticides, pod borer Helicoverpa armigera, Pigeonpea

1. Introduction
Among the important pulses grown in India, pigeonpea belongs to family Leguminosae, is a multipurpose grain legume crop. The green pods of pigeonpea are used as vegetables, grains used as split dal and are rich in protein, averaging a protein digestibility of 70% when cooked (Singh 1991) [7]. It is a staple diet and consumed as green peas as well as dry seeds (Tabo *et al.* 1995) [8]. Globally, the area and production of pigeonpea has increased from 4.43 million hectares (mha) and 3.16 million tonnes (mt) in 2002 to 5.32 mha and 4.32 mt in 2012, respectively (Faostat 2012) [2]. About 250 species of insects belongings to 8 orders and 61 families are found to attack on Pigeonpea. Worldwide, over 30 species of Lepidoptera feed on pods and seeds of Pigeonpea (Shanower *et al.,* 1999) [6]. Among these only few are economically important as pests *viz*., Tur plume moth, *Exelastis atomosa* (Walsh), Tur pod borer, *Helicoverpa armigera* (Hubner) and Tur Pod fly, *Melanagromyza obtusa* (Mall). Which are collectively referred as "Pod borer complex" (Lal, 1998; Patil *et al*., 1990) [3, 5]. This pod borer complex recorded economic damage at various places ranging 30 to 100 percent, as a result we had to import pulses from other countries by investing a huge amount, in addition direct loss to cultivators in the past years. Akkabathula (2014) [1] reported that the management of pod borer complex by newer insecticides spinosad maintained its lethal effect with least percent pod damage (17.77%) which was at par with indoxacarb 18.96% (14.52%), emamectin benzoate 19.54% (14.78%) and acetamiprid 19.14% (14.61%) and showed highest net profit over untreated control (Rs.14769.7/ha). The minimum percent grain damage was also recorded with spinosad 6.30% (8.31%) which was at par with indoxacarb 7.22% (8.91%). Among the tested insecticides, the highest grain yield- 1360.54 kg/ha was recorded with spinosad which was at par with indoxacarb (1122.44 kg/ha). In the untreated control, the yield obtained was 816.32 kg/ha which was lowest of all the insecticides tested. The highest cost benefit ratio (1:9.4) calculated was also with spinosad followed by indoxacarb. Management of Pigeonpea pest is complicated as crop is affected by three groups of insects with different biology and variable population dynamics occurring throughout the year across wider geographical areas. After introduction of the new molecules, which were tested and found effective against the key polyphagous pests. Hence, the present study was mainly focused on the effective management strategies on the pod borer *Helicoverpa armigera* in Pigeonpea at Chhattisgarh.

2. Materials and Methods

A field experiment was laid in randomized block design (RBD) with eight treatments including untreated control, replicated three times. The crop was sown on 30 June 2016 in plot size of 19.20 m2, at the Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) In this experiment number of caterpillars of pod borers was counted randomly selected five plants from each plot, 24 hours before spraying of insecticides as pre treatment and the post treatment counts was taken after 1, 3, 5, 7, 10 days of spraying insecticides. At the time of harvest five plants in each plot were randomly selected and larval populations were recorded. The larval populations were subjected to square root transformation (√). These transformed values were analyzed statistically by using the techniques of analysis of variance for randomized block design and significance was tested by "F" test (Cochran and Cox, 1957). Eight different sequential insecticidal treatments were evaluated including untreated control for the assessment of their comparative performance against pod borers of Pigeon pea. The details of tested insecticides which were applied on Pigeon pea are presented in the Table No. (1.1).

Table 1.1: Insecticides tested against pod borer (*Helicoverpa armigera*) in Pigeon pea

Treatments	Insecticides	Doses(ai/ha)
T1	Control	
T2	Acephate 75SP > Acephate 75SP > Acephate 75SP	750g > 750g > 750g
T3	Acetamiprid 20SP > Acetamiprid 20SP > Acetamiprid 20SP	20g > 20g > 20g
T4	Chlorantraniliprole 18.5 SC > Chlorantraniliprole 18.5SC > Acephate 75SP	30g > 30g > 750g
T5	Chlorantraniliprole 18.5 SC > Chlorantraniliprole 18.5SC > Acetamiprid 20SP	30g > 30g > 20g
T6	Chlorantraniliprole 18.5 SC > Indoxacarb 15.8 EC >Acetamiprid 20SP	30g > 73g > 20g
T7	Chlorantraniliprole 18.5 SC > Flubendiamide 480 SC > Dimethoate 30EC	30g > 30g > 600g
T8	Dimethoate 30EC > Dimethoate 30EC > Dimethoate 30EC	600g>600g > 600g

The quantity of each insecticide was determined for a plot size of 19.20 m^2. The calculated quantity of each insecticide was sprayed with the help of hand operated Knapsack sprayer to which a fine nozzle was attached. The spraying was done three times (first spray at pod formation stage, second and third spray at 15 and 30 days after first spray respectively). Before and after spraying of insecticides, sprayer and measuring cylinder was thoroughly washed with clean water. The data on pod and grain damage were first recorded from the plants and then converted into percent. The percent pod and grain damage were subjected to angular transformation $X=\sqrt{sin^{-1}}$ P, where X= transformed value and P= Percent data. These transformed values and data on grain yield were analyzed statistically by using the techniques of analysis of variance for randomized block design and significance was tested by "F" test (Cochran and Cox, 1957).

The weight of grains were recorded from each plot and converted in to kg/ ha with the help of following formula.

$$\text{Grain Yield (kg/ha)} = \frac{\text{Weight of grains in kg/plot}}{\text{Plot area in m}^2} \times 10000$$

The percent pod and grain damage were subjected to angular transformation X = √sin-1 P

Where X = transformed value and P = Percent data

Percent pod and grain damage was recorded with the help of following formula:

$$\text{Pod damage (\%)} = \frac{\text{Number of damage pods}}{\text{Total number of pods (healthy+damage)}} \times 100$$

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

3. Ressult and discusion

3.1 Larval population of *Helicoverpa armigera* after first spraying

The larval population in the pre treatment observation ranged from 5.00 to 5.33 larvae per plant showing non significant difference between them denoting a uniform population. Table- 2.1 and shows pre treatment and post-treatment observations.

In post treatment observation after first day of first spray, all the tested doses of insecticides showed significant differences over untreated control. Among the treatments, Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha >Acephate 75 SP @ 750g. ai/ha was recorded the best effective treatment with the minimum *Helicoverpa armigera* larval population per plant (0.87) which was at par with Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (0.93), Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.00), Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.07), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.33) and Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.40) The maximum larval population per plant (1.53) was observed in Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha which was least effective treatment. The untreated control significantly differed over rest of treatments with 4.87 larvae per plant.

After third day of first spray, all the treatments showed significant reduction of larvae over control. Among the treatments, Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha showed minimum larval population per plant (0.80) which was at par with Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.87), 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.07), Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.07), Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.27), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.27)

and Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.47). The untreated control significant differed over rest of treatments with 4.67 larvae per plant.

After fifth day of first spray, all the treatments showed significant reduction of larvae over control. Among the treatments, minimum larval population per plant (0.93) was recorded with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha which was at par with Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.93), Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.13), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.20), Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.33), Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.47), The highest larval population per plant (1.60) was recorded in Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha. The untreated control significant differed over rest of treatments with 5.07 larvae per plant.

After seventh day of first spray, all the treatments again showed significant reduction of larvae over control. The plots treated with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha depicted minimum larval population per plant (0.93) which was at par with Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (0.93), Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.07), Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.07), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.27), Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.33). The highest larval population per plant (1.40) was recorded in Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. The untreated control significantly differed over rest of treatments with 5.00 larvae per plant.

After tenth day of first spray, Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha showed minimum larval population per plant (1.00). which was at par with Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.07), Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.07), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.33) and Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.40). followed by Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.47). Maximum larval population per plant (1.73) was observed in Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. Untreated control showed population of 5.13 larvae per plant.

3.2 Larval population of *Helicoverpa armigera* after second spraying

In post treatment observation after first day, all the tested doses of insecticides showed significant differences over control. Among the insecticidal treatments, Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha was recorded best effective with minimum larval population per plant (0.73) which was at par with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha >Acetamiprid 20 SP @ 20g a.i./ha (0.80), Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha(0.87), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.20), Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.33) and Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.33). Maximum larval population per plant (1.40) was observed in Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. The untreated control plot significantly differed over rest of treated plots with 5.07 larvae per plant.

After third day of second spray, all the treatments showed significant reduction of larvae over control. The plots treated with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha showed minimum larval population per plant (0.73). which was at par with Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.80), Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.07), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.13), Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.27), Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (1.40). The highest larval population per plant (1.53) was recorded in Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. The untreated control plot significantly differed over rest of treated plots with 5.20 larvae per plant.

After fifth day of second spray, all the treatments showed significant reduction of larvae over control. Among the treatments, Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha showed minimum larval population per plant (0.80). which was at par Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha >Acetamiprid 20 SP @ 20g a.i./ha (0.93), Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.00) and Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.07). The highest larval population per plant (1.67) was recorded in Treatment 7: Chlorantraniliprole

18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. The untreated control plot significantly differed over rest of treated plots with 5.33 larvae per plant.

After seventh day of second spray, all the treatments showed significant reduction of larvae over control. The plots treated with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha showed minimum larval population per plant (0.80) which was at par with Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.87), Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (0.93), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.20) and Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.59). The highest larval population per plant (1.80) was recorded in Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. The untreated control plot significantly differed over rest of treated plots with 5.40 larvae per plant.

After tenth day of second spray, all the treatments showed significant reduction of larvae over control. The plots treated with Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha showed least larval population per plant (0.93). which was at par with Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.00), Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha >Acetamiprid 20 SP @ 20g a.i./ha (1.00) and Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (1.27).The highest larval population per plant (2.00) was recorded in Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. Untreated control showed population of 5.33 larvae per plant.

3.3 Larval population of *Helicoverpa armigera* after third spraying

In post treatment observation after first day, all the tested doses of insecticides showed significant differences over control. Among the treatments, Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha was recorded best effective with minimum larval population per plant (0.33) which was at par with Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.40), Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (0.40), Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (0.47), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.53) and Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.53). The highest larval population per plant (0.60) was recorded in Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha. The untreated control plot significantly differed over rest of treated plots with 2.93 larvae per plant.

In post treatment observation after third day, all the tested doses of insecticides showed significant differences over control. Among the treatments, Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha was recorded best effective with minimum larval population per plant (0.40) which was at par with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.47), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.47), Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.47), Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (0.47) and Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (0.53). The highest larval population per plant (0.53) was recorded in Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. The untreated control plot significantly differed over rest of treated plots with 2.73 larvae per plant.

In post treatment observation after fifth day, all the tested doses of insecticides showed significant differences over control. Among the treatments, Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha was recorded best effective with minimum larval population per plant (0.40). which was at par with Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (0.40), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.47), Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (0.47), Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha >Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (0.53), Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.60). The highest larval population per plant (0.67) was recorded in Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha The untreated control plot significantly differed over rest of treated plots with 3.27 larvae per plant.

In post treatment observation after seventh day, all the tested doses of insecticides showed significant differences over control. Among the treatments, Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha was recorded best effective with minimum larval population per plant (0.40). which was at par with Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.40), Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (0.47), Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.53), Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (0.53) and Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @

600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (0.53). The maximum larval population per plant (0.60) was recorded in Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. The untreated control plot significantly differed over rest of treated plots with 3.00 larvae per plant.

In post treatment observation after tenth day, all the tested doses of insecticides showed significant differences over control. Among the treatments, Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha was recorded best effective with minimum larval population per plant (0.40). which was at par with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.40), Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (0.47), Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (0.47), Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha and Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (0.53) was recorded best effective with minimum larval population per plant. The highest larval population per plant (0.60) was recorded in Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha. The untreated control plot significantly differed over rest of treated plots with 2.53 larvae per pl.

Table 2.1: Average larval population of Helicoverpa armigera in pre treatment and post treatment observation.

Treatment	Pre - treatment larval population	Post treatment larval population														
		First spray					Second spray					Third spray				
		1st day	3rd day	5th day	7th day	10th day	1st day	3rd day	5th day	7th day	10th day	1st day	3rd day	5th day	7th day	10th day
T1	5.33 (2.52)*	4.87 (2.42)	4.67 (2.37)	5.07 (2.45)	5.00 (2.45)	5.13 (2.48)	5.07 (2.46)	5.20 (2.48)	5.33 (2.52)	5.40 (2.53)	5.33 (2.52)	2.93 (1.97)	2.73 (1.92)	3.27 (2.05)	3.00 (2.00)	2.53 (1.88)
T2	5.00 (2.45)	1.53 (1.59)	1.47 (1.57)	1.60 (1.61)	1.33 (1.53)	1.47 (1.57)	1.33 (1.53)	1.27 (1.50)	1.47 (1.57)	1.53 (1.59)	1.60 (1.61)	0.60 (1.26)	0.53 (1.23)	0.67 (1.29)	0.53 (1.24)	0.53 (1.23)
T3	5.13 (2.48)	1.33 (1.53)	1.27 (1.51)	1.20 (1.48)	1.27 (1.50)	1.33 (1.53)	1.20 (1.48)	1.13 (1.45)	1.07 (1.43)	1.20 (1.48)	1.27 (1.50)	0.53 (1.24)	0.47 (1.21)	0.47 (1.21)	0.40 (1.18)	0.40 (1.18)
T4	5.53 (2.56)	0.87 (1.36)	1.07 (1.44)	1.13 (1.46)	0.93 (1.39)	1.07 (1.44)	0.87 (1.36)	1.07 (1.44)	1.00 (1.41)	0.93 (1.39)	1.00 (1.41)	0.33 (1.15)	0.40 (1.18)	0.47 (1.21)	0.47 (1.21)	0.53 (1.24)
T5	5.20 (2.49)	1.07 (1.44)	0.80 (1.33)	0.93 (1.39)	0.93 (1.38)	1.07 (1.44)	0.80 (1.34)	0.73 (1.32)	0.80 (1.34)	0.80 (1.33)	1.00 (1.41)	0.53 (1.24)	0.47 (1.20)	0.60 (1.26)	0.53 (1.23)	0.40 (1.18)
T6	5.40 (2.53)	1.00 (1.41)	0.87 (1.37)	0.93 (1.39)	1.07 (1.43)	1.00 (1.40)	0.73 (1.31)	0.80 (1.33)	0.93 (1.39)	0.87 (1.35)	0.93 (1.38)	0.40 (1.18)	0.47 (1.21)	0.40 (1.18)	0.40 (1.18)	0.47 (1.21)
T7	5.07 (2.45)	0.93 (1.39)	1.07 (1.44)	1.33 (1.53)	1.07 (1.41)	1.40 (1.55)	1.40 (1.55)	1.53 (1.58)	1.67 (1.63)	1.80 (1.67)	1.87 (1.69)	0.40 (1.18)	0.53 (1.24)	0.53 (1.24)	0.60 (1.27)	0.47 (1.21)
T8	5.40 (2.53)	1.40 (1.55)	1.27 (1.50)	1.47 (1.57)	1.40 (1.54)	1.73 (1.65)	1.33 (1.52)	1.40 (1.55)	1.47 (1.57)	1.60 (1.61)	2.00 (1.73)	0.47 (1.21)	0.47 (1.21)	0.40 (1.18)	0.53 (1.24)	0.60 (1.26)
SE(m)±	0.08	0.07	0.09	0.08	0.10	0.05	0.07	0.10	0.07	0.09	0.06	0.06	0.07	0.08	0.05	0.06
C.D. (5%)	NS	0.20	0.26	0.26	0.30	0.16	0.23	0.30	0.22	0.26	0.18	0.20	0.22	0.23	0.14	0.19

Figures in Parentheses are square root transformed values

T1: Untreated control;

T2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha

T3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha

T4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha

T5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha

T6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha

T7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha

T8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha

Table 2.2: Percent pod and grain damage by *Helicoverpa armigera* and grain yield in different treatments of pigeon pea

Notation	Treatments	Doses (a.i./ha)	Percent pod damage	Percent grain damage	Grain Yield (kg/ha)
T1	**C**ontrol		9.15 (17.58)	4.94 (12.78)	856.42
T2	**A**cephate 75SP > Acephate 75SP > Acephate 75SP	750g > 750g > 750g	5.99 (14.11)	2.85 (9.70)	1058.51
T3	**A**cetamiprid 20SP > Acetamiprid 20SP > Acetamiprid 20SP	20g > 20g > 20g	4.73 (12.45)	2.37 (8.82)	1056.08
T4	**C**hlorantraniliprole 18.5 SC > Chlorantraniliprole 18.5SC > Acephate 75SP	30g > 30g > 750g	5.54 (13.58)	1.95 (7.99)	1107.12
T5	**C**hlorantraniliprole 18.5 SC > Chlorantraniliprole 18.5SC > Acetamiprid 20SP	30g > 30g > 20g	3.98 (11.50)	1.84 (7.70)	1302.08
T6	**C**hlorantraniliprole 18.5 SC > Indoxacarb 15.8 EC >Acetamiprid 20SP	30g > 73g > 20g	4.77 (12.60)	2.28 (8.63)	1192.01
T7	**C**hlorantraniliprole 18.5 SC > Flubendiamide 480 SC > Dimethoate 30EC	30g > 30g > 600g	5.52 (13.56)	2.25 (8.53)	1062.85
T8	**D**imethoate 30EC > Dimethoate 30EC > Dimethoate 30EC	600g > 600g > 600g	6.29 (14.50)	2.96 (9.68)	1135.42
SE(m)±			0.67	0.87	
C.D. at 5%			2.06	2.67	

Figures in Parentheses are angular transformed values

3.4 Percent pod damage by *Helicoverpa armigera*

In case of pod damage by *Helicoverpa armigera*, all the tested newer insecticides were found significantly superior over untreated control. Among the treatments, the minimum percent pod damage by *H.armigera* was recorded with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha >Acetamiprid 20 SP @ 20g a.i./ha(3.98%) which was at par with Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha(4.73%) and Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha(4.77%) followed by Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha(5.52%), Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha(5.54%) and Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha(5.99%) The maximum percent pod damage was recorded in Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (6.29%). pod damage by *H.armigera* recorded in untreated control was 9.15%. (Table 2.2)

3.5 Grain damage by *Helicoverpa armigera*

All the tested newer insecticides were found significantly superior over untreated control. Among the treatments, the minimum grain damage of 1.84% by *Helicoverpa armigera* was recorded with Treatment 5: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha treated plots, which was at par with Treatment 4: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Acephate 75 SP @ 750g a.i./ha (1.95%), Treatment 7: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Flubendiamide 480 SC @ 30g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (2.25%), Treatment 6: Chlorantraniliprole 18.5 SC @ 30g a.i./ha > Indoxacarb 15.8 EC @ 73g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (2.28%), Treatment 3: Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha > Acetamiprid 20 SP @ 20g a.i./ha (2.37%), Treatment 8: Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha > Dimethoate 30 EC @ 600g a.i./ha (2.96%) and Treatment 2: Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha > Acephate 75 SP @ 750g a.i./ha (2.85%). Grain damage by *H.armigera* recorded in untreated control was 4.94%. (Table 2.2).

4. References

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