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Efficacy of chemical insecticides against Pod borer (*Helicoverpa armigera* (Hubner)) on pigeonpea

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Abstract

The different eight chemical insecticides were evaluated against *Helicoverpa armigera* (Hubner) in pigeonpea field during Kharif, 2021-22 and 2022-23. The pooled results showed that the plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly most (0.35 larva/plant) effective and it was followed by flubendiamide 39.35 SC @ 0.008 per cent (0.60 larva/plant), emamectin benzoate 5 SG @ 0.002 per cent (0.80 larva/plant) and spinosad 45 SC @ 0.015 per cent (0.85 larva/plant). Among the evaluated insecticides, the least effective with maximum (1.06 larvae/plant) population was observed in plots treated with novaluron 10 EC @ 0.005 per cent which was superior over untreated control. The significantly higher (1480 kg/ha) seed yield was obtained in plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent and it remained at par with flubendiamide 39.35 SC @ 0.008 per cent (1367 kg/ha). However, the treatment of novaluron 10 EC @ 0.005 per cent recorded minimum (1046 kg/ha) yield.

Keywords: Efficacy, *Helicoverpa armigera*, Insecticides, Pigeonpea, Population, Larva, Plant

Introduction

Pigeonpea [*Cajanus Cajan* (Linnaeus) Millspaugh] is an important grain legume crop of the tropics and sub-tropics. It is also known as tur, arhar and redgram. Pigeonpea is a rich source of protein (22.3%) which supplies a major share of the protein requirement of the vegetarian population of the country, making it a valuable component for improving food security and nutrition for many poor families (Tiwari and Shrivhare, 2016)^[9]. It has better quality fiber, 7g/100g of seeds (Kandhare, 2014)^[4]. Besides its nutritional value, it also possesses various medicinal properties due to the presence of several polyphenols and flavonoids. Pigeonpea is a multi-purpose crop used as dal (split grains), vegetable (green seeds and pods), fodder (green and dry leaves), feed (dry crushed grains) and fuel. It helps in natural nitrogen fixation and can be grown for green manuring. Globally, pigeonpea is grown in an area of 6.03 million hectares with a production of 5.33 million tonnes and productivity of 883.40 kg/ha (FAO, 2022). In India, it is grown on 5.05 million hectares with an annual production and productivity of 4.34 million tonnes and 859 kg/ha, respectively. Maximum economic damage is caused by the insect pests feeding on buds, flowers and pods. Among several insect pests infesting pigeonpea, the lepidopteran pests viz., pod borer, *Helicoverpa armigera* (Hubner); spotted pod borer, *Maruca vitrata* (Geyer); pod fly, *Melanagromyza obtusa* (Malloch); plume moth, *Exelastis atomosa* (Walshingham) and blue butterfly, *Lampides boeticus* (Linnaeus) are most serious. Damage inflicted by *H. armigera* larvae is confined to flowers, seeds and pods and a single larvae can destroy 30-40 pods. Whereas *M. vitrata* larvae causes substantial damage to flowers by webbing and boring into the pods (Sreekanth et al., 2015)^[8]. In India, the pod damage caused by *M. obtusa*, *C. gibbosa*, *H. armigera* and *M. vitrata* has been reported to be 34.4 to 49.9, 23.1 to 47.3, 9.4 to 18.1 and 5.7 to 12.4 per cent, respectively (Keval et al., 2017)^[5]. Considering the above facts, the present investigations are carried out.

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2. Materials and methods

2.1 Experimental details

Table 1: Experimental details

Location	Agronomy Instructional FarmC. P. College of AgricultureS. D. Agricultural UniversitySardarkrushinagar
Year & Season	: Kharif, 2021-22 and 2022-23
Crop and Variety	: Pigeonpea, GT 101
Design	: Randomized Block Design (RBD)
Replications	: 3
No. of treatments	: 9
Plot size i) Gross	: 4.80 m x 4.00 m
ii) Net	: 3.60 m x 3.00 m
Spacing	: 60 cm x 20 cm
Fertilizer	: 25:50:00 - N:P:K (kg/ha)

2.2 Treatment details:

The details of insecticides and their doses used in the present investigation were given as below.

Table 2: Details of treatments imposed in the experiment

Tr. No.	Treatments	Concentration (%)	Dose (g or ml / 10 lit. of water)
T ₁	Chlorantraniliprole 18.5 SC	0.006	3
T ₂	Spinosad 45 SC	0.015	3
T ₃	Flubendiamide 39.35 SC	0.008	2
T ₄	Indoxacarb 14.5 SC	0.01	7
T ₅	Chlorantraniliprole 9.30 + Lambda cyhalothrin 4.60 ZC	0.006	4
T ₆	Novaluron 10 EC	0.005	5
T ₇	Profenofos 40 + Cypermethrin 4 EC	0.088	20
T ₈	Emamectin benzoate 5 SG	0.002	4
T ₉	Untreated control	-	-

2.3 Application of insecticides

The first spray was applied at 50 % flowering and second spray at 15 days after first spray. The spray volume for treatment was calibrated by spraying water in control plot. Spraying was done by using knapsack sprayer in early morning hours.

2.4 Observations recorded

The number of *H. armigera* larvae was counted on five randomly selected plants from each treatment one day before and three, seven and fifteen days after application of treatment.

3. Results and discussion

A field experiment was conducted at the Agronomy Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, during Kharif, 2021-22 and 2022-23 to investigate the efficacy of different chemical insecticides against management of *H. armigera* in pigeonpea.

3.1 First year (2021-22)

3.1.1 First spray

The results showed that significantly lowest (0.48 larva/plant) population was recorded in the treatment of chlorantraniliprole 18.5 SC @ 0.006 per cent which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.73 larva/plant) at three days after first spray. The treatments emamectin benzoate 5 SG @ 0.002 per cent (0.92 larva/plant), spinosad 45 SC @ 0.015 per cent (0.96 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (1.02 larvae/plant), indoxacarb 14.5 SC @ 0.010 per cent (1.06 larvae/plant), profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (1.11 larva/plant) and novaluron 10 EC @ 0.005 per cent (1.15 larvae/plant) were at par with each other. The untreated control recorded the highest population of 2.18 larvae per plant.

Table 3: Efficacy of different chemical insecticides against *H. armigera* on pigeonpea during 2021-22

Tr. No.	Treatments	Conc. (%)	DBS	No. of larvae/plant								Pooled over period over spray
				1 st spray				2 nd spray				
				3 DAS	7 DAS	15 DAS	Pooled over period	3 DAS	7 DAS	15 DAS	Pooled over period	
T ₁	Chlorantraniliprole 18.5 SC	0.006	1.64(2.18)	0.99 ^a (0.48)	0.95 ^a (0.40)	0.97 ^a (0.44)	0.97 ^a (0.44)	0.89 ^a (0.30)	0.86 ^a (0.24)	0.88 ^a (0.27)	0.88 ^a (0.27)	0.92 ^a (0.35)
T ₂	Spinosad 45 SC	0.015	1.65(2.23)	1.21 ^{ab} (0.96)	1.17 ^{ab} (0.88)	1.20 ^{ab} (0.93)	1.19 ^{cd} (0.92)	1.14 ^{ab} (0.80)	1.10 ^{bc} (0.72)	1.13 ^{bc} (0.77)	1.12 ^{cd} (0.75)	1.16 ^c (0.85)
T ₃	Flubendiamide 39.35 SC	0.008	1.64(2.20)	1.11 ^{ab} (0.73)	1.07 ^{ab} (0.64)	1.09 ^{ab} (0.69)	1.09 ^{ab} (0.69)	1.03 ^{ab} (0.55)	0.99 ^{ab} (0.48)	1.01 ^{ab} (0.52)	1.01 ^{ab} (0.52)	1.05 ^{ab} (0.60)
T ₄	Indoxacarb 14.5 SC	0.010	1.66(2.25)	1.25 ^{ab} (1.06)	1.22 ^{ab} (0.99)	1.24 ^{ab} (1.03)	1.24 ^{cd} (1.03)	1.20 ^{ab} (0.93)	1.15 ^{bc} (0.82)	1.17 ^{bc} (0.88)	1.17 ^{cde} (0.88)	1.20 ^{cde} (0.94)

T ₅	Chlorantraniliprole 9.30 + Lambda cyhalothrin 4.60 ZC	0.006	1.63(2.16)	1.23 ^{ab} (1.02)	1.20 ^{ab} (0.94)	1.21 ^{ab} (0.97)	1.22 ^{cd} (0.99)	1.17 ^{ab} (0.86)	1.13 ^{bc} (0.78)	1.15 ^{bc} (0.82)	1.15 ^{cde} (0.82)	1.18 ^{cd} (0.89)
T ₆	Novaluron 10 EC	0.005	1.64(2.20)	1.28 ^{ab} (1.15)	1.26 ^{ab} (1.09)	1.27 ^{ab} (1.12)	1.27 ^{ad} (1.12)	1.23 ^{ab} (1.02)	1.20 ^{ac} (0.94)	1.22 ^{ac} (0.99)	1.22 ^{ae} (0.99)	1.25 ^{ae} (1.06)
T ₇	Profenofos 40 + Cypermethrin 4 EC	0.088	1.65(2.22)	1.27 ^{ab} (1.11)	1.24 ^{ab} (1.04)	1.26 ^{ab} (1.08)	1.26 ^{cd} (1.08)	1.22 ^{ab} (0.99)	1.17 ^{bc} (0.88)	1.20 ^{bc} (0.95)	1.20 ^{de} (0.95)	1.23 ^{de} (1.01)
T ₈	Emamectin benzoate 5 SG	0.002	1.65(2.23)	1.19 ^{ab} (0.92)	1.15 ^{ab} (0.83)	1.18 ^{ab} (0.89)	1.17 ^{bc} (0.87)	1.11 ^{ab} (0.73)	1.09 ^{bc} (0.68)	1.10 ^{bc} (0.70)	1.10 ^{ac} (0.70)	1.14 ^{ac} (0.80)
T ₉	Untreated control	-	1.60(2.06)	1.64 ^{ac} (2.18)	1.68 ^{ac} (2.31)	1.69 ^{ac} (2.37)	1.67 ^{ae} (2.29)	1.73 ^{ac} (2.51)	1.78 ^{ad} (2.66)	1.83 ^{ad} (2.86)	1.78 ^{af} (2.66)	1.73 ^{af} (2.49)
S. Em. ±		T	0.08	0.06	0.06	0.06	0.03	0.06	0.06	0.06	0.03	0.02
		P	-	-	-	-	0.02	-	-	-	0.02	0.01
		S	-	-	-	-	-	-	-	-	-	0.01
		T×P	-	-	-	-	0.06	-	-	-	0.06	0.04
		T×S	-	-	-	-	-	-	-	-	-	0.03
		P×S	-	-	-	-	-	-	-	-	-	0.02
		T×P×S	-	-	-	-	-	-	-	-	-	0.06
C. D. at 5%		T	N.S.	0.18	0.17	0.18	0.08	0.18	0.17	0.18	0.08	0.06
C. V. (%)				8.92	8.47	8.19	8.27	8.32	8.50	8.24	8.52	7.97

Figures in parentheses are retransformed values of $\sqrt{(X+0.5)}$ transformed values

Treatment means with the letter(s) in common are not significantly different by DNMRT at 5% level of significance

The data on population of pod borer recorded at seven days after first spray indicated that chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly most effective treatment which showed lowest population (0.40 larva/plant) which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.64 larva/plant). The treatments emamectin benzoate 5 SG @ 0.002 per cent, spinosad 45 SC @ 0.015 per cent, chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent, indoxacarb 14.50 SC @ 0.010 per cent, profenofos 40 + cypermethrin 4 EC @ 0.088 per cent and novaluron 10 EC @ 0.005 per cent were found to be the next best group of treatments which were statistically at par with each other as they recorded 0.83, 0.88, 0.94, 0.99, 1.04 and 1.09 larvae per plant, respectively.

Fifteen days after first spray, significantly maximum (2.37 larvae/plant) population was recorded in untreated control. The lowest population (0.44 larva/plant) was recorded from plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.69 larva/plant). Emamectin benzoate 5 SG @ 0.002 per cent (0.89 larva/plant), spinosad 45 SC @ 0.015 per cent (0.93 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.97 larva/plant), indoxacarb 14.50 SC @ 0.010 per cent (1.03 larva/plant), profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (1.08 larva/plant) and novaluron 10 EC @ 0.005 per cent (1.12 larvae/plant) were par with each other.

The mean results of pooled over period data after first spray presented in Table 3.1 revealed that the plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent was found significantly most effective which showed lowest (0.44 larva/plant) population which was followed by flubendiamide 39.35 SC @ 0.008 per cent (0.69 larva/plant). The next best effective group of treatment was emamectin benzoate 5 SG @ 0.002 per cent with 0.87 larva per plant which was followed by spinosad 45 SC @ 0.015 per cent (0.92 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.99 larva/plant), indoxacarb 14.5 SC @ 0.010 per cent (1.03 larvae/plant) and profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (1.08 larvae/plant). Among the studied insecticides, plots treated with novaluron 10 EC @ 0.005 per cent was least effective (1.12 larva/plant) but was superior over the untreated control (2.29 larvae/plant).

3.1.2 Second spray

The results showed that lowest (0.30 larva/plant) population was recorded in the treatment of chlorantraniliprole 18.5 SC @ 0.006 per cent which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.55 larva/plant) at three days after second spray. Emamectin benzoate 5 SG @ 0.002 per cent (0.73 larva/plant), spinosad 45 SC @ 0.015 per cent (0.80 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.86 larva/plant), indoxacarb 14.5 SC @ 0.010 per cent (0.93 larva/plant), profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (0.99 larva/plant) and novaluron 10 EC @ 0.005 per cent (1.02 larvae/plant) were at par with each other but superior over untreated control (2.51 larvae/plant).

At seven days after second spray of insecticides revealed that chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly the best effective treatment (0.24 larva/plant) which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.48 larva/plant). The treatments emamectin benzoate 5 SG @ 0.002 per cent, spinosad 45 SC @ 0.015 per cent, chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent, indoxacarb 14.5 SC @ 0.010 per cent and profenofos 40 + cypermethrin 4 EC @ 0.088 per cent were the next best group of treatments which were statistically at par with each other as they recorded 0.68, 0.72, 0.78, 0.82 and 0.88 larva per plant, respectively. Plot treated with novaluron 10 EC @ 0.005 per cent was significantly least (0.94 larva/plant) effective but was superior over the untreated control (2.66 larvae/plant).

Fifteen days after second spray chlorantraniliprole 18.5 SC @ 0.006 per cent recorded lowest (0.27 larva/plant) population which remained at par with flubendiamide 39.35 SC @ 0.015 per cent (0.52 larva/plant). The remaining treatments of emamectin benzoate 5 SG @ 0.002 per cent (0.70 larva/plant), spinosad 45 SC @ 0.015 per cent (0.77 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.82 larva/plant), indoxacarb 14.5 SC @ 0.010 per cent (0.88 larva/plant) and profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (0.95 larva/plant) were at par with each other. Novaluron 10 EC @ 0.005 per cent was significantly least (0.99 larva/plant) effective.

Pooled over period data after second spray (Table 3.1) showed that significantly maximum population was observed in untreated plots with 2.66 larvae per plant while the plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent was found

significantly most effective treatment which showed lowest population 0.27 larva per plant which was followed by flubendiamide 39.35 SC @ 0.008 per cent (0.52 larva/plant) and emamectin benzoate 5 SG @ 0.002 per cent (0.70 larva per plant). The next best effective group of treatment was spinosad 45 SC @ 0.015 per cent (0.75 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.82 larva/plant) and indoxacarb 14.5 SC @ 0.010 per cent (0.88 larva/plant). Among the tested insecticides, significantly maximum (0.99 larva/plant) population was observed in the plots treated with novaluron 10 EC @ 0.005 per cent.

3.2 Second year (2022-23)

The data revealed that the *H. armigera* population before spray was evenly distributed throughout all the plots, between 1.87

and 2.05 larvae per plant but was not statistically significant (Table 3.2).

3.2.1 First spray

Significantly lowest (0.40 larva/plant) population was recorded from the treatment chlorantraniliprole 18.5 SC @ 0.006 per cent, which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.63 larva/plant) at three days after first spray. Emamectin benzoate 5 SG @ 0.002 per cent (0.84 larva/plant), spinosad 45 SC @ 0.015 per cent (0.88 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.94 larva/plant), indoxacarb 14.5 SC @ 0.010 per cent (0.99 larvae/plant), profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (1.04 larvae/plant) and

Table 4: Efficacy of different chemical insecticides against *H. armigera* on pigeonpea during 2022-23

Tr. No.	Treatments	Conc. (%)	DBS	No. of larvae/plant								Pooled over period over spray
				1 st spray				2 nd spray				
				3 DAS	7 DAS	15 DAS	Pooled over period	3 DAS	7 DAS	15 DAS	Pooled over period	
T ₁	Chlorantraniliprole 18.5 SC	0.006	1.57(1.98)	0.95 ^a (0.40)	0.89 ^a (0.29)	0.91 ^a (0.33)	0.92 ^a (0.35)	0.85 ^a (0.22)	0.79 ^a (0.13)	0.82 ^a (0.18)	0.82 ^a (0.18)	0.87 ^a (0.26)
T ₂	Spinosad 45 SC	0.015	1.59(2.03)	1.17 ^b (0.88)	1.12 ^{bc} (0.76)	1.15 ^b (0.83)	1.15 ^{cd} (0.83)	1.10 ^{bc} (0.72)	1.05 ^{bc} (0.61)	1.08 ^{bc} (0.66)	1.08 ^{cd} (0.66)	1.11 ^{cd} (0.73)
T ₃	Flubendiamide 39.35 SC	0.008	1.58(2.00)	1.06 ^{ab} (0.63)	1.01 ^{ab} (0.51)	1.04 ^{ab} (0.58)	1.04 ^b (0.58)	0.98 ^{ab} (0.46)	0.92 ^{ab} (0.35)	0.95 ^{ab} (0.41)	0.95 ^b (0.41)	1.00 ^b (0.50)
T ₄	Indoxacarb 14.5 SC	0.010	1.60(2.05)	1.22 ^{ab} (0.99)	1.17 ^{bc} (0.88)	1.20 ^b (0.94)	1.20 ^{cd} (0.94)	1.15 ^{bc} (0.82)	1.10 ^c (0.71)	1.13 ^{bc} (0.78)	1.13 ^{cde} (0.78)	1.16 ^{def} (0.85)
T ₅	Chlorantraniliprole 9.30 + Lambda cyhalothrin 4.60 ZC	0.006	1.57(1.96)	1.20 ^{ab} (0.94)	1.14 ^{bc} (0.81)	1.17 ^b (0.86)	1.17 ^{cd} (0.86)	1.13 ^{bc} (0.77)	1.08 ^{bc} (0.66)	1.10 ^{bc} (0.72)	1.10 ^{cde} (0.72)	1.14 ^{cde} (0.80)
T ₆	Novaluron 10 EC	0.005	1.58(2.00)	1.26 ^{ab} (1.09)	1.22 ^c (0.98)	1.24 ^b (1.05)	1.24 ^d (1.05)	1.20 ^c (0.94)	1.15 ^c (0.83)	1.18 ^c (0.89)	1.18 ^e (0.89)	1.21 ^f (0.96)
T ₇	Profenofos 40 + Cypermethrin 4 EC	0.088	1.59(2.02)	1.24 ^{ab} (1.04)	1.20 ^c (0.93)	1.22 ^b (0.99)	1.22 ^{cd} (0.99)	1.17 ^{bc} (0.88)	1.13 ^c (0.77)	1.15 ^{bc} (0.82)	1.15 ^{de} (0.82)	1.19 ^{ef} (0.92)
T ₈	Emamectin benzoate 5 SG	0.002	1.59(2.03)	1.16 ^{ab} (0.84)	1.11 ^{bc} (0.73)	1.13 ^{ab} (0.78)	1.13 ^c (0.78)	1.07 ^{bc} (0.64)	1.01 ^{bc} (0.53)	1.04 ^{bc} (0.58)	1.04 ^c (0.58)	1.09 ^c (0.69)
T ₉	Untreated control	-	1.54(1.87)	1.58 ^c (2.01)	1.63 ^d (2.15)	1.65 ^c (2.23)	1.62 ^e (2.12)	1.67 ^d (2.30)	1.70 ^d (2.40)	1.73 ^d (2.48)	1.70 ^f (2.39)	1.66 ^g (2.26)
S. Em. ±		T	0.08	0.06	0.05	0.06	0.03	0.06	0.05	0.06	0.03	0.02
		P	-	-	-	-	0.02	-	-	-	0.02	0.01
		S	-	-	-	-	-	-	-	-	-	0.01
		T×P	-	-	-	-	0.06	-	-	-	0.06	0.04
		T×S	-	-	-	-	-	-	-	-	-	0.03
		P×S	-	-	-	-	-	-	-	-	-	0.02
		T×P×S	-	-	-	-	-	-	-	-	-	0.05
C. D. at 5%		T	N.S.	0.18	0.16	0.18	0.08	0.17	0.16	0.17	0.08	0.06
C. V. (%)			8.79	8.69	8.06	8.51	8.43	8.54	8.36	8.76	8.56	8.09

Figures in parentheses are retransformed values of $\sqrt{(X+0.5)}$ transformed values

Treatment means with the letter(s) in common are not significantly different by DNMRT at 5% level of significance novaluron 10 EC @ 0.005 per cent (1.09 larvae/plant) were at par with each other but superior over untreated control (2.01 larvae/plant).

The population of *H. armigera* recorded at seven days after first spray of insecticides revealed that chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly the most valuable treatment that saw lowest 0.29 larva per plant which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.51 larva/plant). The treatments emamectin benzoate 5 SG @ 0.002 per cent, spinosad 45 SC @ 0.015 per cent, chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent and indoxacarb 14.5 SC @ 0.010 per cent were next best group of treatments which were statistically at par with each other as they recorded 0.73, 0.76, 0.81 and 0.88 larva per plant, respectively. Novaluron 10 EC @ 0.005 per cent was the significantly least (0.98 larva/plant) effective treatment.

Fifteen days after first spray, the lowest population (0.33 larva/plant) was recorded from plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent, which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.58 larva/plant). The subsequent successful group of treatments were emamectin benzoate 5 SG @ 0.002 per cent (0.78 larva/plant), spinosad 45 SC @ 0.015 per cent (0.83 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.86 larva/plant), indoxacarb 14.5 SC @ 0.010 per cent (0.94 larva/plant), profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (0.99 larva/plant) and novaluron 10 EC @ 0.005 per cent (1.05 larvae/plant) which were at par with each other.

The mean findings of pooled over data after first spray indicated that chlorantraniliprole 18.5 SC @ 0.006 per cent was the significantly most effective treatment which showed lowest population of 0.35 larva per plant which was followed by flubendiamide 39.35 SC @ 0.008 per cent (0.58 larva/plant) and emamectin benzoate 5 SG @ 0.002 per cent (0.78 larva/plant).

The next best effective group of treatments were spinosad 45 SC @ 0.015 per cent (0.83 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.86 larva/plant), indoxacarb 14.5 SC @ 0.010 per cent (0.94 larva/plant) and profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (0.99 larva/plant). The plots treated with novaluron 10 EC @ 0.005 per cent was significantly least effective (1.05 larva/plant) but was superior over the untreated control. The untreated control recorded the highest population of 2.12 larvae per plant.

3.2.2 Second spray

The findings indicated that significantly lowest (0.22 larva/plant) population was recorded from plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent which remained at par with flubendiamide 39.35 SC @ 0.008 per cent (0.46 larva/plant) at three days after second spray. The next effective group of treatments were emamectin benzoate 5 SG @ 0.002 per cent (0.64 larva/plant), spinosad 45 SC @ 0.015 per cent (0.72 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.77 larva/plant), indoxacarb 14.5 SC @ 0.010 per cent (0.82 larva/plant) and profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (0.88 larva/plant) which were at par with each other. Novaluron 10 EC @ 0.005 per cent was determined to be the least effective (0.94 larva/plant).

After seven days of second application of insecticides, chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly most effective treatment with lowest (0.13 larva/plant) population which was at par with flubendiamide 39.35 SC @ 0.008 per cent (0.35 larva/plant). However, remaining of the insecticide treatments were significantly superior over untreated control (2.40 larvae/plant).

The significantly lowest (0.18 larva/plant) population was recorded from plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent which was at par with flubendiamide 39.35 SC @ 0.015 per cent (0.41 larva/plant) at fifteen days after second spray. The next best effective treatments were emamectin benzoate 5 SG @ 0.002 per cent (0.58 larva/plant), spinosad 45

SC @ 0.015 per cent (0.66 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.72 larva/plant), indoxacarb 14.5 SC @ 0.010 per cent (0.78 larva/plant) and profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (0.82 larva/plant) which were at par with each other but superior over untreated control (2.48 larvae/plant).

The results of pooled over period data after second spray showed that the plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly most effective treatment which showed that lowest population (0.18 larva/plant) which was followed by flubendiamide 39.35 SC @ 0.008 per cent (0.41 larva/plant) and emamectin benzoate 5 SG @ 0.002 per cent (0.58 larva/plant). The next best effective group of treatment was spinosad 45 SC @ 0.015 per cent (0.66 larva/plant), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.72 larva/plant) and indoxacarb 14.5 SC @ 0.010 per cent (0.78 larva/plant). The significantly maximum (0.89 larva/plant) population was observed in plots treated with novaluron 10 EC @ 0.005 per cent which was found superior over untreated control. The maximum population was observed in untreated plots (2.39 larvae/plant).

3.3 Pooled over year (2021-22 and 2022-23)

The pooled data (2021-22 and 2022-23) for their efficacy of different chemical insecticides against management of *H. armigera* populations are presented in Table 3.3. The results showed that the population of *H. armigera*, a day before spray was homogeneously distributed in all plots, ranging between 1.96 and 2.16 larvae per plant, which was statistically non significant.

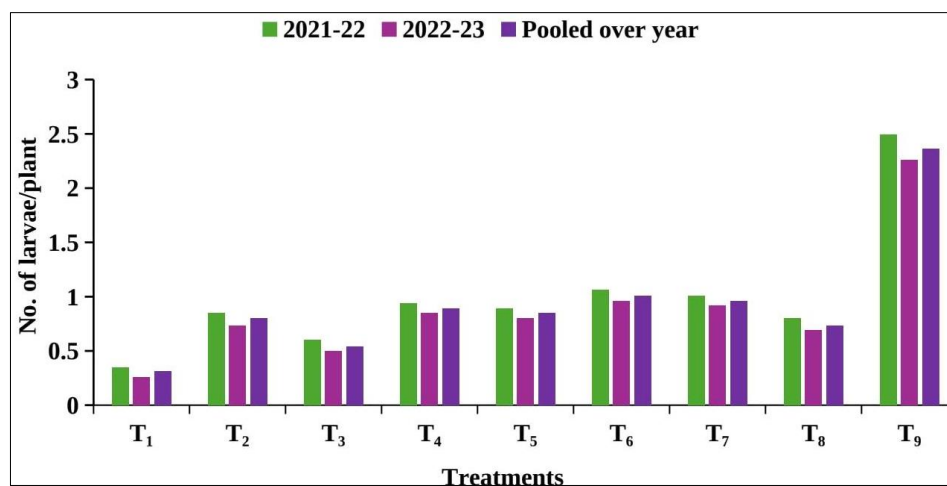
During 2021-22, the results of pooled over period data after second spray are presented in Table 3.3 and Fig.1 showed that the plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly most (0.35 larva/plant) effective and it was followed by flubendiamide 39.35 SC @ 0.008 per cent (0.60 larva/plant), emamectin benzoate 5 SG @ 0.002 per cent (0.80 larva/plant) and spinosad 45 SC @ 0.015 per cent (0.85 larva/plant).

Table 5: Efficacy of different chemical insecticides against *H. armigera* on pigeonpea (Pooled)

Tr. No.	Treatments	Conc. (%)	Day before spray	No. of larvae/plant		
				Year		Pooled over year
				2021-22	2022-23	
T ₁	Chlorantraniliprole 18.5 SC	0.006	1.60(2.06)	0.92 ^a (0.35)	0.87 ^a (0.26)	0.90 ^a (0.31)
T ₂	Spinosad 45 SC	0.015	1.62(2.12)	1.16 ^a (0.85)	1.11 ^{cd} (0.73)	1.14 ^{cd} (0.80)
T ₃	Flubendiamide 39.35 SC	0.008	1.61(2.09)	1.05 ^{ab} (0.60)	1.00 ^{ab} (0.50)	1.02 ^{ab} (0.54)
T ₄	Indoxacarb 14.5 SC	0.010	1.63(2.16)	1.20 ^{cde} (0.94)	1.16 ^{def} (0.85)	1.18 ^{def} (0.89)
T ₅	Chlorantraniliprole 9.30 + Lambda cyhalothrin 4.60 ZC	0.006	1.60(2.06)	1.18 ^{cd} (0.89)	1.14 ^{cde} (0.80)	1.16 ^{cde} (0.85)
T ₆	Novaluron 10 EC	0.005	1.61(2.09)	1.25 ^{de} (1.06)	1.21 ^{ef} (0.96)	1.23 ^{ef} (1.01)
T ₇	Profenofos 40 + Cypermethrin 4 EC	0.088	1.62(2.12)	1.23 ^{de} (1.01)	1.19 ^{ef} (0.92)	1.21 ^{ef} (0.96)
T ₈	Emamectin benzoate 5 SG	0.002	1.62(2.12)	1.14 ^c (0.80)	1.09 ^{ac} (0.69)	1.11 ^{ac} (0.73)
T ₉	Untreated control	-	1.57(1.96)	1.73 ^f (2.49)	1.66 ^g (2.26)	1.69 ^g (2.36)
	S.Em. ±	T	0.06	0.02	0.02	0.02
		P	-	0.01	0.01	0.01
		S	-	0.01	0.01	0.01
		Y	0.03	-	-	0.01
		T×P	-	0.04	0.04	0.03
		T×S	-	0.03	0.03	0.02
		P×S	-	0.02	0.02	0.01
		Y×T	0.08	-	-	0.02
		Y×P	-	-	-	0.01
		Y×S	-	-	-	0.01

	T×P×S	-	0.06	0.05	0.04
	Y×S×T	-	-	-	0.03
	Y×S×P	-	-	-	0.02
	Y×P×T	-	-	-	0.04
	Y×S×P×T	-	-	-	0.06
C. D. at 5%	T	NS	0.06	0.06	0.04
	Y×T	-	-	-	NS
C. V. (%)		8.86	7.97	8.09	8.03

Figures in parentheses are retransformed values of $\sqrt{(X+0.5)}$ transformed values Treatment means with the letter(s) in common are not significantly different by DNMRT at 5% level of significance



T₁=Chlorantraniliprole 18.5 SC, T₂=Spinosad 45 SC, T₃=Flubendiamide 39.35 SC, T₄=Indoxacarb 14.5 SC, T₅=Chlorantraniliprole 9.30 + Lambda cyhalothrin 4.60 ZC, T₆=Novaluron 10 EC, T₇=Profenofos 40 +

Fig 1:Efficacy of different chemical insecticides against *H. armigera* on pigeonpea

The next best effective group was chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.89 larva/plant) and indoxacarb 14.5 SC @ 0.010 per cent (0.94 larva/plant) which were at par with each other. However, remaining insecticide treatments were significantly superior over untreated control. Among the evaluated insecticides, the least effective with maximum (1.06 larvae/plant) population was observed in plots treated with novaluron 10 EC @ 0.005 per cent which was superior over untreated control. The maximum population was observed in untreated plots with 2.49 larvae per plant.

During 2022-23, the results of pooled over period data after second spray are presented in Table 3.3 and illustrated in Fig. 1 revealed that significantly lowest (0.26 larva/plant) population was recorded in the plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent which was followed by flubendiamide 39.35 SC @ 0.008 per cent (0.50 larva/plant) and emamectin benzoate 5 SG @ 0.002 per cent (0.69 larva/plant). The next effective treatments were spinosad 45 SC @ 0.015 per cent (0.73 larva/plant) and chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.80 larva/plant) which were at par with each other. However, the plots treated with novaluron 10 EC @ 0.005 per cent was significantly least (0.96 larva/plant) effective but which was superior over the untreated control. The significantly highest (2.26 larvae/plant) population of *H. armigera* was observed in untreated control plots. The results of pooled over data of the first and second year (Table 3.3 and Fig. 1) showed that chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly most effective with lowest population 0.31 larva per plant which was followed by flubendiamide 39.35 SC @ 0.008 per cent (0.54 larva/plant) and emamectin benzoate 5 SG @ 0.002 per cent with 0.73 larva per plant. The next valuable group of treatment was spinosad 45 SC @ 0.015 per cent (0.80 larva/plant) and chlorantraniliprole 9.30 +

lambda cyhalothrin 4.6 ZC @ 0.006 per cent (0.85 larva/plant) which were statistically at par with each other. However, remaining insecticidal treatments were significantly superior over untreated control. Finally, novaluron 10 EC at 0.005 per cent was determined significantly least (1.01 larvae/plant) effective and was superior over untreated control. The untreated control recorded 2.36 larva per plant.

Earlier, Patange and Chiranjeevi (2017) [6] at Parbhani, Maharashtra reported that chlorantraniliprole 18.5 SC @ 30 g a.i./ha was the most effective insecticide in minimizing the larval population and also shown the lowest pod damage (5.59 %) due to pigeonpea pod borers and recorded highest gain yield of pigeonpea (7.60 q/ha). Dadas *et al.* (2019) [1] at Parbhani, Maharashtra revealed that chlorantraniliprole 18.5 SC was the most promising treatment to minimize the larval population of *H. armigera* with minimum population of 0.47 larva per plant followed by flubendiamide 39.37% SC (0.56 larva/plant) and indoxacarb 14.5 SC (0.66 larva/plant) after first and second spray. Jagtap *et al.* (2023) [3] at Rahuri, Maharashtra reported that spraying of chlorantraniliprole 18.5 EC (0.30 ml/lit.) at fortnightly interval was the most effective treatment in controlling pod borers and also gave the highest grain yield (30.54 q/ha) of pigeonpea. Thus, results of present study are in close conformity with that reported by earlier workers.

3.4 Seed yield

3.4.1 First year (2021-22)

The data on seed yield of pigeonpea obtained after application of various treatments are presented in Table 3.4. The significantly higher yield of pigeonpea (1370 kg/ha) was obtained in plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent and remained at par with flubendiamide 39.35 SC @ 0.008 per cent with 1240 kg per ha and emamectin benzoate 5 SG @ 0.002 per cent with 1179 kg per ha during the

year 2021-22. However, the treatments of spinosad 45 SC @ 0.015 per cent (1105 kg/ha), chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent (1089 kg/ha) and indoxacarb 14.5 SC @ 0.010 per cent (1038 kg/ha) were

statistically at par with each other. The plots treated with remaining treatments recorded less yield which varied from 1001 to 990 kg per ha but performed superior over untreated control (723 kg/ha).

Table 6: Impact of different chemical insecticides on seed yield of pigeonpea

Tr. No.	Treatments	Conc. (%)	Seed yield (kg/ha)		
			Year		Pooled over year
			2021-2022	2022-2023	
T ₁	Chlorantraniliprole 18.5 SC	0.006	1370 ^a	1590 ^a	1480 ^a
T ₂	Spinosad 45 SC	0.015	1105 ^{bc}	1305 ^{bcd}	1205 ^{cd}
T ₃	Flubendiamide 39.35 SC	0.008	1240 ^{ab}	1494 ^{ab}	1367 ^{ab}
T ₄	Indoxacarb 14.5 SC	0.010	1038 ^{bc}	1219 ^{cd}	1129 ^{de}
T ₅	Chlorantraniliprole 9.30 + Lambda cyhalothrin 4.60 ZC	0.006	1089 ^{bc}	1257 ^{bcd}	1173 ^{cde}
T ₆	Novaluron 10 EC	0.005	990 ^c	1102 ^d	1046 ^e
T ₇	Profenofos 40 + Cypermethrin 4 EC	0.088	1001 ^c	1166 ^{cd}	1084 ^{de}
T ₈	Emamectin benzoate 5 SG	0.002	1179 ^{abc}	1413 ^{abc}	1296 ^{bc}
T ₉	Untreated control	-	723 ^d	808 ^e	765 ^f
S. Em. ±		T	70.44	77.87	48.56
		Y	-	-	24.75
		Y×T	-	-	74.25
C. D. at 5%		T	211.17	233.45	138.78
		Y×T	-	-	NS
C. V. (%)			11.28	10.69	10.98

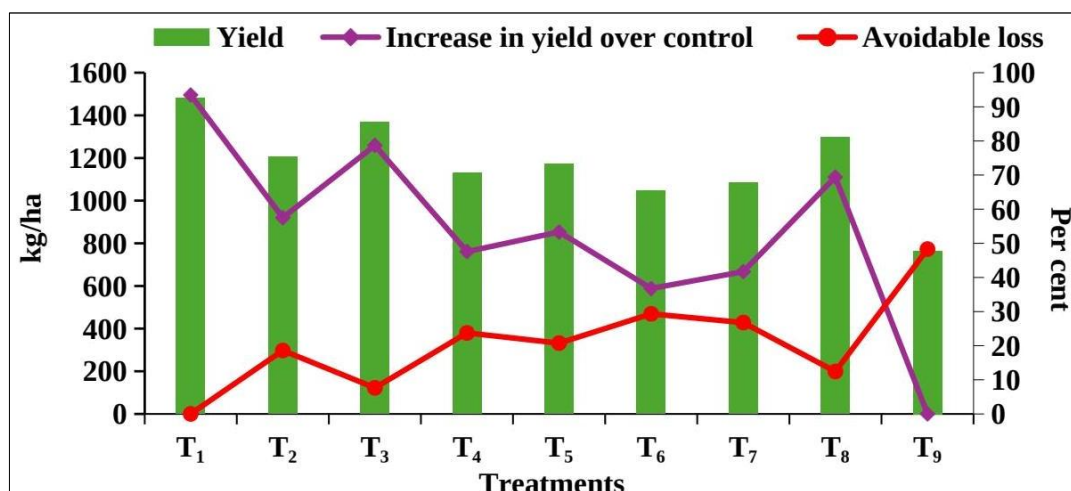
Treatment means with the letter(s) in common are not significantly different by DNMRT at 5% level of significance

3.4.2 Second year (2022-23)

The results indicated that all the treatments performed significantly superior over untreated control (808 kg/ha). The significantly maximum yield was recorded in the treatment chlorantraniliprole 18.5 SC @ 0.006 per cent (1590 kg/ha) which was statistically at par with flubendiamide 39.35 SC @ 0.008 per cent (1494 kg/ha) and emamectin benzoate 5 SG @ 0.002 per cent (1413 kg/ha). The treatments of spinosad 45 SC @ 0.015 per cent, chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent and indoxacarb 14.5 SC @ 0.010 per cent was statistically at par with each other and formed second best group of effective treatments during the second year which recorded grain yield of 1305, 1257 and 1219 kg per ha, respectively. Among the studied insecticides, novaluron 10 EC @ 0.005 per cent recorded significantly minimum (1102 kg/ha) yield.

3.4.3 Pooled over year (2021-22 and 2022-23)

The pooled results of 2021-22 and 2022-23 obtained on seed yield of pigeonpea are provided in Table 3.4 and represented in Fig. 2 revealed that significantly higher (1480 kg/ha) yield was obtained in plots treated with chlorantraniliprole 18.5 SC @ 0.006 per cent and it remained at par with flubendiamide 39.35 SC @ 0.008 per cent (1367 kg/ha). The treatments of emamectin benzoate 5 SG @ 0.002 per cent, spinosad 45 SC @ 0.015 per cent, chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent and indoxacarb 14.5 SC @ 0.010 per cent recorded moderate yield of pigeonpea 1296, 1205, 1173 and 1129 kg per ha, respectively. The treatments comprised of profenofos 40 + cypermethrin 4 EC @ 0.088 per cent (1084 kg/ha) and novaluron 10 EC @ 0.005 per cent (1046 kg/ha) recorded minimum yield but performed superior over untreated control plots (765 kg/ha).



T₁=Chlorantraniliprole 18.5 SC, T₂=Spinosad 45 SC, T₃=Flubendiamide 39.35 SC, T₄=Indoxacarb 14.5 SC, T₅=Chlorantraniliprole 9.30 + Lambda cyhalothrin 4.60 ZC, T₆=Novaluron 10 EC, T₇=Profenofos 40 + Cypermethrin 4 EC, T₈=Emamectin benzoate 5 SG, T₉=Untreated control

Fig 2: Effect of different chemical insecticides on seed yield, increase in yield over untreated control and avoidable loss in pigeonpea (Pooled Patange and Chiranjeevi (2017) [6] at Parbhani, Maharashtra studied that chlorantraniliprole 18.5 SC @ 30 g a.i./ha was the most effective insecticide in minimizing the larval population and also shown the lowest pod damage (5.59%) due to

pigeonpea pod borers and recorded highest grain yield of pigeonpea (7.60 q/ha). Sonune and Bhamare (2018) [2] at Parbhani, Maharashtra found that the significantly maximum grain yield, gross and net profit was recorded in the plots treated with the chlorantraniliprole 18.5 SC (8.79 q /ha with Rs. 20400/- and Rs.14150/-) followed by flubendiamide 39.37 SC (7.83 q/ha. with Rs. 15650/- and Rs.14020/-). Jagtap *et al.* (2023) [3] at Rahuri, Maharashtra reported that spraying of chlorantraniliprole 18.5% EC (0.30 ml/lit.) at fortnightly interval was most effective in controlling pod borers and also gave the highest grain yield (30.54 q/ha) of pigeonpea. Thus, the current study's findings are broadly consistent with those reported by previous researchers.

3.5 Increase in yield over untreated control

The pooled data on increase in yield over untreated control are presented in Table 3.5 and depicted in Fig. 2. The results indicated that maximum increase in yield over untreated control was observed in the treatment of chlorantraniliprole 18.5 SC @ 0.006 per cent (93.46%) followed by flubendiamide 39.35 SC @ 0.008 per cent (78.69%) and emamectin benzoate 5 SG @ 0.002 per cent (69.41%). The treatments of spinosad 45 SC @ 0.015 per cent, chlorantraniliprole 9.30 + lambda cyhalothrin 4.6 ZC @ 0.006 per cent and indoxacarb 14.50 SC @ 0.010 per cent recorded 57.52, 53.33 and 47.58 per cent increase in yield over untreated control, respectively. The plots treated with novaluron 10 EC @ 0.005 per cent recorded lowest (36.73%) increase in yield over untreated control.

Table 7: Effect of different chemical insecticides on increase in yield over untreated control and avoidable loss in pigeonpea

Tr. No.	Treatments	Conc. (%)	Increase in yield over untreated control (%)			Avoidable loss (%)		
			Year		Average	Year		Average
			2021-22	2022-23		2021-22	2022-23	
T ₁	Chlorantraniliprole 18.5 SC	0.006	89.49	96.78	93.46	-	-	-
T ₂	Spinosad 45 SC	0.015	52.84	61.51	57.52	19.34	17.92	18.58
T ₃	Flubendiamide 39.35 SC	0.008	71.51	84.90	78.69	9.49	6.04	7.64
T ₄	Indoxacarb 14.5 SC	0.010	43.57	50.87	47.58	24.23	23.33	23.72
T ₅	Chlorantraniliprole 9.30 + Lambda cyhalothrin 4.60 ZC	0.006	50.62	55.57	53.33	20.51	20.94	20.74
T ₆	Novaluron 10 EC	0.005	36.93	36.39	36.73	27.74	30.69	29.32
T ₇	Profenofos 40 + Cypermethrin 4 EC	0.088	38.45	44.31	41.70	26.93	26.67	26.76
T ₈	Emamectin benzoate 5 SG	0.002	63.07	74.88	69.41	13.94	11.13	12.43
T ₉	Untreated control	-	-	-	-	47.23	49.18	48.31

3.6 Avoidable loss

The pooled result on avoidable losses in yield is presented in Table 4.28 and graphically depicted in Fig. 4.11. The results revealed that the avoidable loss in pigeonpea crop sprayed with various treatments varied from 7.64 to 48.31 per cent. The plots treated with flubendiamide 39.35 SC @ 0.008 per cent found least avoidable loss with 7.64 per cent followed by emamectin benzoate 5 SG @ 0.002 per cent (12.43%). Moreover, the highest avoidable loss showed in untreated control plots with 48.31 per cent.

4. Conclusion

The present study revealed that the treatment of chlorantraniliprole 18.5 SC @ 0.006 per cent was significantly most effective which recorded lowest (0.31 larva/plant) population *H. armigera* and higher (1480 kg/ha) seed yield. The treatment of novaluron 10 EC @ 0.005 per cent was significantly the least (1.01 larvae/plant) effective and recorded minimum (1046 kg/ha) yield amongst all tested insecticides.

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