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EFFICACY OF NEW INSECTICIDES AGAINST POD BORER COMPLEX OF PIGEONPEA

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ABSTRACT

Studies on effect of new insecticides on the pod borer complex of pigeonpea were carried out at Main Agicultural Research Station, University of Agricultural Sciences, Dharwad during 2022-23. Insecticides possessing newer mode of action with dual effectivity were tested. Among the various insecticides Isocycloserum 10% DC @ 1.25 mL/L greatly outperformed other more recent pesticides in terms of detecting the lowest incidence of pod damage from both borers and pod fly in field conditions. For pod borers, Emamectin benzoate 5% + Lufenuron 40 % WG @ 0.15 g/L and Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC @ 0.40 mL/L were the next-best treatments. The next two most effective treatments for pod fly were Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC @ 0.40 mL/L and Thiamethoxam 25% WG + Jaggery (0.3 g + 10 g). Further Isocycloserum 10% DC had the highest grain output and benefit cost ratio.

Key words : Pigeon pea, Pod borer, Pod fly, Insecticides.

Introduction

Pigeonpea, *Cajanus cajan* (L.) commonly known as redgram, tur, arhar is an erect and short lived perennial leguminous shrub. It belongs to the genus *Cajanus* of the family Fabaceae. It is originated in India and is having a chromosome number of 2n = 22. Because of its deep tap root system, resilience to heat and rapid growth pattern, this tropical and subtropical plant is well suited for rainfed agriculture in semiarid regions (Mallikarjuna *et al.*, 2011). It is a legume with 20 to 24 per cent proteins, 1.2 per cent fats, 66 per cent carbohydrates and 3.8 per cent ash (Aykroyd *et al.*, 1982).

Pigeonpea is grown in an area of 69.93 lakh hectares across the world, producing 59.61 million tonnes and yielding 812.42 kg per ha. In terms of acreage, output and productivity, India comes in front. Pigeonpea is grown on 42.3 lakh hectares of land in India, with production and productivity of 38.9 lakh tonnes and 919 kg per ha, respectively (Anonymous, 2019). Maharashtra, Madhya Pradesh, Uttar Pradesh, Gujarat, Jharkhand, Telangana and Andhra Pradesh are major pigeonpea growing states in India. In Karnataka, the principal pigeonpea growing areas are Kalburgi, Bidar, Vijaypura, Dharwad and Raichur.

The pigeonpea crop was being attacked by a total of 30 insect pests throughout it's growth stages. Out of these, two pests, *Helicoverpa armigera* and *Aceria cajani*, were recorded as major pests on this crop causing more than 51 per cent damage to the crop, whereas eleven insects, *Megalurothrips usitatus*, *Empoasca kerri*, *Clavigralla gibbosa*, *Riptortus pedestris*, *Exelastis atomosa*, *Melanagromyza obtusa*, *Cydia ptychora*, *Maruca testulalis*, *Etiella zinckenella*, *Adisura atkinsoni* and *Mylabris pustulata* were recorded as moderate pests by causing damage ranging between 31 to 50 per cent. For this crop, ten insect pests were counted as inconsequential pests, while as many as seven insect pests were listed as minor pests (Balikai and Yelshetty, 2008).

The crop is extremely vulnerable to attack from a variety of insect pests, both in field and in storage. Of the several pests that attack the crop, pests that attack during

the reproductive stage of the crop results in significant yield loss. Pests that infest pods causes significant damage to the crop, which reduces the overall production. Pest management by chemical insecticides should be the last resort when the insect population reaches above economic threshold level. The newer insecticides with different modes of action are paving a potential way of reducing the pod borer pests. To test the effectiveness of some newer pesticides against the pod borer complex of pigeonpea the following experiment was conducted.

Materials and Methods

A field experiment was conducted in Randomized Block Design during *kharif* season at Main Agricultural Research Station, Dharwad with 7 treatments including an untreated check. Each treatment was replicated thrice. The variety TS-3R was sown in plots of 4.5 m × 4.2 m maintaining a spacing of 90 cm × 30 cm. The crop was raised as per the recommended agronomic practices of UAS, Dharwad.

Treatment was imposed twice starting from flower initiation period and at 15 days interval after the first spray. Untreated check was maintained to compare the data. Observation on insect population and pod damage of pod borer complex was recorded one day before spray and 3, 7 and 14 days after spray. Larval population per plant of pod borer complex *viz.*, *Helicoverpa armigera* and *Maruca vitrata* were recorded randomly on selected five plants but in case of *Melanagromyza obtusa*, the number of maggot population on ten randomly selected pods per plant was recorded at fifteen day interval.

A total of 100 pods from five randomly selected plants were plucked and examined in the laboratory at fortnightly intervals from pod bearing stage for the damage caused by the insects. On the basis of external symptoms as well as the type of injury done to the grains, the pods were sorted our into four groups *viz.*, pods damaged by *Helicoverpa armigera*, *Maruca vitrata*, *Melanagromyza obtusa* and healthy pods. The percentage of pod damage was calculated on the basis of damaged pods to the total number of pods observed. The parameters of grain yield (q/ha) and Benefit Cost Ratio was also estimated

$$\text{Per cent pod damage} = \frac{\text{Number of damaged pods}}{\text{Total number of pods}} \times 100$$

Results and Discussion

Helicoverpa armigera

First spray : A day before treatment application, the incidence of gram pod borer did not differ significantly. One day after spray all the treatments were significantly superior over untreated check in reducing the gram pod borer population, The treatment Isocycloserum 10% DC (T_1) was found to be significantly superior in reducing the population to 0.92 larvae per plant. However, it was on par with Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60 % ZC (0.98 larvae/plant) and Emamectin benzoate 5% + Lufenuron 40% WG (1.02 larvae/plant). The observation recorded on seven days after spraying revealed that the least population of gram pod borer was recorded in Isocycloserum 10% DC (0.61 larvae/plant) and was followed by Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC (0.67 larvae/plant) and Emamectin benzoate 5% + Lufenuron 40 % WG (0.72 larvae/plant) which were on par with each other. Almost similar trend was noticed at fourteen days after spraying (Table 1).

Second spray : One day after spraying, Isocycloserum 10% DC recorded significantly lower population of 0.43 larvae per plant. Next best treatments were Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60% ZC (0.52 larvae/plant) and Emamectin benzoate 5% + Lufenuron 40% WG (0.57 larvae/plant). Thiamethoxam 25% WG + Jaggery recorded significantly higher population among the insecticidal treatments (2.01 larvae/plant). However, all the treatments stood significantly superior over untreated check (3.63 larvae/plant). Superiority of Isocycloserum 10% DC was noticed even after seven days and fourteen days after spraying compared to rest of the treatments (Table 1).

The mean *H. armigera* larval population after the spraying of insecticides, across the treatments indicated that least population of larvae was recorded in Isocycloserum 10% DC with 0.57 larvae per plant followed by Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60 % ZC (0.65 larvae/plant) and Emamectin benzoate 5% + Lufenuron 40% WG (0.69 larvae/plant). However, Thiamethoxam 25% WG + Jaggery was found to be least effective by registering the highest population of *H. armigera* larvae, *i.e.*, 2.05 per plant (Table 1).

Similar trend was observed with respect to per cent pod damage by *Helicoverpa armigera* for both first and second sprays on third, seventh and fourteenth days of observation after spray where, Isocycloserum was found most effective in reducing pod damage (Table 2).

Maruca vitrata

First spray : The observations recorded at three days after the first spray revealed that Isocycloserum 10% DC recorded 2.25 larvae per plant which was on par with Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC (2.31 larvae/plant) and Emamectin benzoate 5% + Lufenuron 40% WG (2.38 larvae/plant). The next

Table 1 : Efficacy of new insecticides against gram pod borer, *Helicoverpa armigera* in pigeonpea during 2022-23.

Tr. no.	Treatments	Number of larvae per plant								
			1st spray			2nd spray			Mean	ROC(%)
		1 DBS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T_1	Isocycloseram 10 DC @ 1.25 mL/L	2.34(1.53)	0.92(0.97)[a]	0.61(0.78)[a]	0.77(0.87)[a]	0.43(0.67)[a]	0.30(0.55)[a]	0.37(0.62)[a]	0.57	82.52
T_2	Emamectin Benzoate 5 % + Lufenuron 40 % WG @ 0.15 g/L	2.48(1.58)	1.02(1.02)[a]	0.72(0.84)[b]	0.90(0.95)[a]	0.57(0.75)[b]	0.41(0.63)[b]	0.50(0.71)[b]	0.69	78.83
T_3	Beta-cyfluthrin 8.49 % + Imidacloprid 19.81 % ZC @ 1 mL/L	2.42(1.56)	1.34(1.16)[b]	1.13(1.06)[c]	1.32(1.14)[b]	1.06(1.03)[c]	0.86(0.93)[c]	0.97(0.98)[c]	1.12	65.64
T_4	Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60 % ZC @ 0.40 mL/L	2.43(1.55)	0.98(1.00)[a]	0.67(0.82)[b]	0.85(0.95)[a]	0.52(0.73)[ab]	0.38(0.60)[b]	0.47(0.68)[ab]	0.65	80.06
T_5	Chlorantraniliprole 18.5 % SC @ 0.15 mL/L	2.36(1.54)	1.42(1.20)[b]	1.18(1.08)[c]	1.38(1.17)[b]	1.14(1.06)[c]	0.95(0.98)[c]	1.06(1.03)[c]	1.19	63.50
T_6	Thiamethoxam 25% WG + Jaggery @ 0.3 g + 10 g/L	2.57(1.61)	1.98(1.41)[c]	1.82(1.34)[d]	2.28(1.52)[c]	2.01(1.41)[d]	1.87(1.37)[d]	2.32(1.52)[d]	2.05	38.03
T_7	Untreated control	2.45(1.57)	2.92(1.71)[d]	3.25(1.81)[e]	3.57(1.89)[d]	3.63(1.90)[e]	3.24(1.80)[e]	2.97(1.72)[e]	3.26	-
	S.Em ±	**NS**	**0.02**	**0.02**	**0.02**	**0.03**	**0.02**	**0.02**	-	
	CD (P=0.05)	**NS**	**0.06**	**0.05**	**0.05**	**0.07**	**0.06**	**0.06**	-	
	CV (%)	**8.40**	**7.76**	**8.82**	**9.46**	**8.22**	**9.02**	**8.68**	-	

Figures in parentheses square root transformed values; Means in column followed by same alphabet do not differ significantly by DMRT (P = 0.05); DBS - Day Before Spray; DAS - Days After Spray; ROC – Reduction Over Control.

best treatment was Beta-cyfluthrin 8.49% + Imidacloprid 19.81% ZC (2.66 larvae/plant) which was on par with Chlorantraniliprole 18.5% SC (2.70 larvae/plant), followed by Thiamethoxam 25% WG + Jaggery (3.17 larvae/plant). However, untreated check registered highest number of larvae/plant (4.74 larvae/plant). Similar trend was noticed on seventh and fourteenth days after spraying (Table 3).

Second spray : After three days of the second spray, the results showed significant differences among the treatments. Lowest number of larvae per plant was recorded with Isocycloserum 10% DC (1.02 larvae/plant), followed by Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC (1.16 larvae/plant) and Emamectin benzoate 5% + Lufenuron 40% WG (1.22 larvae/plant) which showed equal effect. On seventh day after spray, trend was alike with superiority of Isocycloserum 10% DC (0.66 larvae/plant), followed by T_4 (0.81 larvae/plant) and T_2 (0.87 larvae/plant) which were on par with each other. On fourteenth day after spraying, Isocycloserum 10% DC recorded the least number of larvae per plant (0.82). However, untreated control remained inferior by recording highest larval population (6.67 larvae/plant) (Table 3).

The mean larval population after the spraying of insecticides across the treatments indicated that least population of larvae recorded in Isocycloserum 10% DC (1.40 larvae/plant) followed by Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC with the population of 1.53 larvae per plant. Whereas, Thiamethoxam 25% WG + Jaggery treated plot recorded highest population of 3.18 larvae per plant (Table 3). Similar trend was observed with respect to per cent pod damage by spotted pod borer, where Isocycloserum was found most effective in reducing pod damage (Table 4).

Table 2 : Efficacy of new insecticides against pod damage by gram pod borer, *Helicoverpa armigera* in pigeonpea during 2022-23.

Tr. no.	Treatments	Per cent pod damage								
		1st spray				2nd spray			Mean	ROC(%)
		DBS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T_1	Isocycloseram 10 DC @ 1.25 mL/L	15.85 (23.46)	9.26 (17.71)[a]	7.92 (16.33)[a]	8.62 (17.09)[a]	5.92 (14.06)[a]	4.52 (12.26)[a]	5.01 (12.97)[a]	6.88	72.31
T_2	Emamectin Benzoate 5 % + Lufenuron 40 % WG @ 0.15 g/L	16.27 (23.78)	10.12 (18.53)[a]	8.78 (17.22)[a]	9.68 (18.14)[a]	7.28 (15.67)[b]	5.89 (14.06)[b]	6.38 (14.61)[b]	8.02	67.72
T_3	Beta-cyfluthrin 8.49 % + Imidacloprid 19.81 % ZC @ 1 mL/L	16.02 (23.60)	11.01 (19.36)[b]	9.87 (18.33)[b]	10.97 (19.33)[b]	9.41 (17.85)[c]	8.06 (16.50)[c]	8.59 (17.05)[c]	9.65	61.17
T_4	Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60 % ZC @ 0.40 mL/L	16.12 (23.65)	9.76 (18.20)[a]	8.43 (16.87)[a]	9.33 (17.78)[a]	6.83 (15.15)[ab]	5.43 (13.47)[b]	5.92 (14.05)[ab]	7.62	69.33
T_5	Chlorantraniliprole 18.5 % SC @ 0.15 mL/L	15.87 (23.47)	11.27 (19.61)[b]	10.13 (18.53)[b]	11.23 (19.58)[b]	9.67 (18.14)[c]	8.33 (16.78)[c]	8.86 (17.32)[c]	9.92	60.08
T_6	Thiamethoxam 25 % WG + Jaggery @ 0.3 g + 10 g/L	16.35 (23.86)	15.60 (23.26)[c]	15.12 (22.86)[c]	15.80 (23.42)[c]	14.91 (22.70)[d]	14.48 (22.38)[d]	15.82 (23.44)[d]	15.29	38.47
T_7	Untreated control	16.11 (23.65)	19.56 (26.25)[d]	25.78 (30.52)[d]	27.82 (31.82)[d]	27.26 (31.47)[e]	25.42 (30.26)[e]	23.23 (28.81)[e]	24.85	-
	S.Em ±	**NS**	**0.35**	**0.34**	**0.36**	**0.34**	**0.31**	**0.32**	-	-
	CD (P=0.05)	**NS**	**1.04**	**1.03**	**1.09**	**1.01**	**0.94**	**0.96**	-	-
	CV (%)	**10.26**	**11.64**	**10.20**	**10.34**	**11.68**	**9.89**	**11.87**	-	-

Figures in parentheses are angular transformed values; Means in column followed by same alphabet do not differ significantly by DMRT (P = 0.05); DBS - Day Before Spray; DAS - Days After Spray; ROC – Reduction Over Control.

Table 3 : Efficacy of new insecticides against spotted pod borer, *Maruca vitrata* in pigeonpea during 2022-23.

Tr. no.	Treatments	Number of larvae per plant								
		1st spray				2nd spray			Mean	ROC(%)
		1 DBS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T_1	Isocycloseram 10 DC @ 1.25 mL/L	3.54(1.88)	2.25(1.50)^{a}	1.75(1.32)^{a}	1.92(1.38)^{a}	1.02(1.02)^{a}	0.66(0.81)^{a}	0.82(0.92)^{a}	1.40	77.35
T_2	Emamectin Benzoate 5 % + Lufenuron 40 % WG @ 0.15 g/L	3.62(1.91)	2.38(1.55)^{a}	1.91(1.38)^{a}	2.10(1.45)^{a}	1.22(1.11)^{b}	0.87(0.93)^{b}	1.05(1.03)^{b}	1.59	74.27
T_3	Beta-cyfluthrin 8.49 % + Imidacloprid 19.81 % ZC @ 1 mL/L	3.45(1.86)	2.66(1.63)^{b}	2.27(1.51)^{b}	2.50(1.59)^{b}	1.65(1.29)^{c}	1.31(1.14)^{c}	1.51(1.22)^{c}	1.98	67.96
T_4	Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60 % ZC @ 0.40 mL/L	3.61(1.90)	2.31(1.52)^{a}	1.88(1.37)^{a}	2.06(1.44)^{a}	1.16(1.10)^{b}	0.81(0.89)^{b}	0.98(1.00)^{ab}	1.53	75.24
T_5	Chlorantraniliprole 18.5 % SC @ 0.15 mL/L	3.45(1.86)	2.70(1.64)^{b}	2.42(1.55)^{b}	2.65(1.63)^{b}	1.83(1.35)^{c}	1.51(1.24)^{c}	1.77(1.33)^{c}	2.15	65.21
T_6	Thiamethoxam 25 % WG + Jaggery @ 0.3 g + 10 g/L	3.57(1.89)	3.17(1.78)^{c}	3.02(1.73)^{c}	3.49(1.87)^{c}	3.12(1.76)^{d}	2.98(1.73)^{d}	3.28(1.81)^{d}	3.18	48.54
T_7	Untreated control	3.43(1.85)	4.74(2.18)^{d}	5.32(2.31)^{d}	6.42(2.53)^{d}	6.87(2.62)^{e}	7.04(2.65)^{e}	6.67(2.58)^{e}	6.18	-
	S.Em ±	**NS**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	-	-
	CD (P=0.05)	**NS**	**0.09**	**0.08**	**0.08**	**0.07**	**0.08**	**0.08**	-	-
	CV (%)	**9.46**	**8.88**	**8.27**	**9.29**	**10.06**	**9.52**	**8.62**	-	-

Figures in parentheses are square root transformed values; Means in column followed by same alphabet do not differ significantly by DMRT (P = 0.05); DBS - Day Before Spray; DAS - Days After Spray.

Melanagromyza obtusa

First spray : A day before spraying of insecticides the maggot population varied from 4.97 to 5.10 maggots per 10 pods. However, no significant difference was observed among the treatments. At three days after spray, from the results obtained, it was observed that there was significant difference among the treatments. The lowest maggot population was recorded in the treatment Isocycloserum 10% DC (2.01 maggots / 10 pods), which was followed by Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60% ZC (2.32 maggots / 10 pods) and Thiamethozam 25% WG + Jaggery (2.34 maggots / 10 pods), which were on par with each other. On seventh and fourteenth days after spraying, the difference among the treatments against maggot population of *M. obtusa* was significant. A similar trend of insecticides efficacy was noted on both the days of observation as that of third day. Isocycloserum 10% DC recorded lowest number of maggot population per 10 pods followed by Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC and Thiamethozam 25% WG + Jaggery, which were found on par with each other. Significantly highest maggot population was recorded in Chlorantraniliprole 18.5% SC (Table 5).

Second spray : During second spray lowest number of maggots per 10 pods (0.71) was registered by Isocycloserum 10% DC on third day of observation. Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC and Thiamethozam 25% WG + Jaggery were found to be the next best treatments in terms of reducing the maggot population and were on par with each other. Seven days after spray, population varied between 0.32 to 7.02 maggots per 10 pods. Isocycloserum was found effective in reducing the pod fly population which recorded least population of 0.32 maggots per 10 pods. The observations recorded at 14 days after the second spray revealed that Isocycloserum 10% DC

Table 4 : Efficacy of new insecticides against pod damage by spotted pod borer, *Maruca vitrata* in pigeonpea during 2022-23.

Tr. no.	Treatments	Per cent pod damage								
		1st spray				2nd spray			Mean	ROC(%)
		1 DBS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T_1	Isocycloseram 10 DC @ 1.25 mL/L	13.31 (21.39)	9.26 (17.71)[a]	7.66 (16.06)[a]	8.48 (16.94)[a]	5.47 (13.51)[a]	4.22 (11.83)[a]	5.27 (13.25)[a]	6.72	59.44
T_2	Emamectin Benzoate 5 % + Lufenuron 40 % WG @ 0.15 g/L	13.22 (21.30)	9.82 (18.24)[a]	8.28 (16.71)[a]	9.23 (17.69)[a]	6.45 (14.73)[b]	5.35 (13.39)[b]	6.47 (14.73)[b]	7.60	54.13
T_3	Beta-cyfluthrin 8.49 % + Imidacloprid 19.81 % ZC @ 1 mL/L	13.97 (21.94)	11.01 (19.36)[b]	9.81 (18.24)[b]	10.78 (19.15)[b]	8.81 (17.25)[c]	7.74 (16.14)[c]	8.94 (17.39)[c]	9.52	42.54
T_4	Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60 % ZC @ 0.40 mL/L	12.85 (21.01)	9.42 (17.88)[a]	7.87 (16.28)[a]	8.82 (17.25)[a]	6.02 (14.17)[b]	4.82 (12.65)[b]	5.92 (14.05)[ab]	7.15	56.85
T_5	Chlorantraniliprole 18.5 % SC @ 0.15 mL/L	13.03 (21.13)	11.22 (19.58)[b]	9.98 (18.43)[b]	10.96 (19.34)[b]	9.02 (17.46)[c]	7.92 (16.36)[c]	9.07 (17.52)[c]	9.70	41.46
T_6	Thiamethoxam 25 % WG + Jaggery @ 0.3 g + 10 g/L	13.87 (21.86)	12.57 (20.79)[c]	11.75 (20.06)[c]	13.06 (21.19)[c]	12.78 (20.96)[d]	11.87 (20.15)[d]	12.97 (21.13)[d]	12.50	24.56
T_7	Untreated control	12.87 (21.02)	13.86 (21.89)[d]	14.42 (22.30)[d]	16.56 (24.01)[d]	18.04 (25.10)[e]	18.36 (26.10)[e]	18.18 (26.39)[e]	16.57	-
	S.Em ±	**NS**	**0.33**	**0.31**	**0.33**	**0.30**	**0.28**	**0.30**	-	-
	CD (P=0.05)	**NS**	**1.00**	**0.93**	**1.00**	**0.90**	**0.83**	**0.88**	-	-
	CV (%)	**10.32**	**11.41**	**10.66**	**10.24**	**11.56**	**11.23**	**10.48**	-	-

Figures in parentheses are angular transformed values; Means in column followed by same alphabet do not differ significantly by DMRT (P = 0.05); DBS - Day Before Spray; DAS - Days After Spray; ROC – Reduction Over Control.

Table 5 : Efficacy of new insecticides against tur pod fly, *Melanagromyza obtusa* in pigeonpea during 2022-23.

Tr. no.	Treatments	Number of maggots / 10 pods								
			1st spray			2nd spray			Mean	ROC(%)
		1 DBS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T_1	Isocycloseram 10 DC @ 1.25 mL/L	5.02(2.24)	2.01(1.42)^{a}	1.38(1.17)^{a}	1.57(1.28)^{a}	0.71(0.84)^{a}	0.32(0.55)^{a}	0.45(0.67)^{a}	1.07	83.22
T_2	Emamectin Benzoate 5 % + Lufenuron 40 % WG @ 0.15 g/L	5.04(2.25)	2.98(1.73)^{d}	2.48(1.58)^{d}	2.72(1.64)^{d}	2.35(1.54)^{d}	2.03(1.42)^{d}	2.21(1.48)^{d}	2.46	61.44
T_3	Beta-cyfluthrin 8.49 % + Imidacloprid 19.81 % ZC @ 1 mL/L	4.98(2.23)	2.63(1.62)^{c}	2.03(1.43)^{c}	2.23(1.49)^{c}	1.78(1.34)^{c}	1.31(1.14)c	1.48(1.22)^{c}	1.91	70.06
T_4	Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60 % ZC @ 0.40 mL/L	5.10(2.26)	2.32(1.52)^{b}	1.72(1.32)^{b}	1.91(1.39)^{b}	1.12(1.05)^{b}	0.62(0.80)^{ab}	0.76(0.88)^{b}	1.41	77.90
T_5	Chlorantraniliprole 18.5 % SC @ 0.15 mL/L	5.08(2.25)	4.06(2.02)^{e}	3.61(1.90)^{e}	4.23(2.06)^{e}	3.91(1.97)^{e}	3.60(1.90)^{e}	3.87(1.97)^{e}	3.88	39.18
T_6	Thiamethoxam 25 % WG + Jaggery @ 0.3 g + 10 g/L	5.10(2.26)	2.34(1.52)^{b}	1.77(1.33)^{b}	1.96(1.40)^{b}	1.21(1.11)^{b}	0.73(0.86)^{b}	0.87(0.93)^{b}	1.48	76.80
T_7	Untreated control	4.97(2.23)	5.02(2.24)^{f}	5.76(2.40)^{f}	6.48(2.55)^{f}	6.76(2.60)^{f}	7.02(2.65)^{f}	7.25(2.70)^{f}	6.38	-
	S.Em±	**NS**	**0.03**	**0.03**	**0.03**	**0.02**	**0.03**	**0.03**	-	-
	CD (P=0.05)	**NS**	**0.09**	**0.08**	**0.08**	**0.07**	**0.08**	**0.09**	-	-
	CV (%)	**8.86**	**10.32**	**9.40**	**10.23**	**9.21**	**9.97**	**11.27**	-	-

Figures in parentheses are square root transformed values; Means in column followed by same alphabet do not differ significantly by DMRT (P = 0.05); DBS - Day Before Spray; DAS - Days After Spray; ROC – Reduction Over Control.

recorded the lowest population of 0.45 maggots per 10 pods. All the applied treatments were found superior over untreated check which recorded 7.25 maggots per 10 pods (Table 5).

The data on overall mean of pod fly maggot population recorded on 3, 7 and 14 days after spraying showed the superiority of all the treatments in reducing the maggots population over untreated control. Amongst all the treatments, Isocycloserum 10% DC was found to be most effective with mean maggot population of 1.07 maggots per 10 pods and significantly superior over all other treatments (Table 5). Similar trend was noticed in the observations recorded for per cent pod damage caused by pod fly presented in Table 6.

An efficient method for managing pesticide resistance has been found to be the combination of different control methods and the use of insecticides with diverse modes of action (Zhu *et al*., 2016). Isocycloseurum is found to be effective against both borers possessing chewing type of mouth parts and podfly with sucking type. A new isoxazoline insecticide and acaricide, Isocycloseram is active against pest species of lepidoptera, hemiptera, coleoptera, thysanoptera and diptera. The invertebrate Rdl GABA receptor is specifically targeted by Isocycloseram at a location different from that of fiproles and organochlorines. Isocycloseram is suitable for controlling pest infestations with this resistance mechanism, as shown by the fact that the widely dispersed cyclodiene resistance mutation, A301S, has no impact on sensitivity to it *in vitro* or *in vivo*. Compared to avermectins, fiproles and organochlorines, it has different effects, which helps in controlling both borers and sucking pests in a very effective manner (Blythe *et al*., 2022).

Due to its multiple modes of action, Ampligo Insecticide is very successful in controlling insect pests. It delivers a

Table 6 : Efficacy of new insecticides against pod damage caused by tur pod fly, *Melanagromyza obtusa* in pigeonpea during 2022-23.

Tr. no.	Treatments	Per cent pod damage								
		1st spray				2nd spray			Mean	ROC(%)
		1 DBS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
T_1	Isocycloseram 10 DC @ 1.25 mL/L	13.26 (21.35)	9.27 (17.71)[a]	7.52 (15.90)[a]	8.46 (16.90)[a]	5.96 (14.16)[a]	4.26 (11.90)[a]	5.01 (12.97)[a]	6.75	71.10
T_2	Emamectin Benzoate 5 % + Lufenuron 40 % WG @ 0.15 g/L	13.34 (21.41)	11.06 (19.43)[bc]	10.16 (18.62)[bc]	11.13 (19.49)[b]	9.33 (17.79)[d]	8.03 (16.46)[d]	8.75 (17.22)[d]	9.74	58.29
T_3	Beta-cyfluthrin 8.49 % + Imidacloprid 19.81 % ZC @ 1 mL/L	13.31 (21.38)	10.42 (18.81)[b]	9.16 (17.62)[b]	10.11 (18.53)[bc]	7.91 (16.32)[c]	6.46 (14.73)[c]	7.36 (15.74)[c]	8.57	63.30
T_4	Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60 % ZC @ 0.40 mL/L	13.28 (21.35)	9.88 (18.33)[ab]	8.38 (16.84)[ab]	9.27 (17.71)[ab]	6.72 (15.04)[b]	5.17 (13.18)[ab]	5.97 (14.13)[b]	7.57	67.58
T_5	Chlorantraniliprole 18.5 % SC @ 0.15 mL/L	13.25 (21.36)	11.77 (20.06)[c]	10.57 (19.00)[c]	12.56 (20.76)[c]	11.23 (19.58)[e]	10.33 (18.72)[e]	12.06 (20.33)[e]	11.42	51.16
T_6	Thiamethoxam 25 % WG + Jaggery @ 0.3 g + 10 g/L	13.33 (21.41)	9.95 (18.40)[ab]	8.45 (16.91)[ab]	9.42 (17.85)[ab]	6.87 (15.18)[b]	5.22 (13.18)[b]	6.03 (14.22)[b]	7.66	67.19
T_7	Untreated control	13.17 (21.27)	19.41 (26.13)[d]	21.68 (27.76)[d]	22.62 (28.40)[d]	24.48 (29.64)[f]	25.87 (30.58)[f]	26.02 (30.65)[f]	23.35	-
	S.Em ±	**NS**	**0.34**	**0.34**	**0.35**	**0.33**	**0.33**	**0.31**	-	-
	CD (P=0.05)	**NS**	**1.03**	**1.01**	**1.06**	**1.00**	**1.00**	**0.94**	-	-
	CV (%)	**10.55**	**10.33**	**10.21**	**10.46**	**11.12**	**11.47**	**10.30**	-	-

Figures in parentheses are angular transformed values; Means in column followed by same alphabet do not differ significantly by DMRT (P = 0.05); DBS - Day Before Spray; DAS - Days After Spray; ROC – Reduction Over Control.

Table 7 : Cost effectiveness of newer insecticides in the management of pod borer complex of pigeonpea during 2022-23.

Tr. no.	Treatments	Yield (q/ha)	Increase in yield over control (%)	Cost of protection (Rs/ha)	Total cost (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T_1	Isocycloseram 10% DC @ 1.25 mL/L	14.62[a]	67.66	5010	29510	77486	47976	1 : 2.63
T_2	Emamectin Benzoate 5%+ Lufenuron 40 % WG @ 0.15 g/L	12.62[b]	44.72	1077	25577	66886	41309	1 : 2.61
T_3	Beta-cyfluthrin 8.49 % + Imidacloprid 19.81 % ZC @ 1 mL/L	12.98[b]	48.85	2000	26500	68794	42294	1 : 2.60
T_4	Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60% ZC @ 0.40 mL/L	13.05[b]	49.65	5666	30166	69165	38999	1 : 2.30
T_5	Chlorantraniliprole 18.5% SC @ 0.15 mL/L	10.93[c]	25.34	1560	26060	57929	31869	1 ; 2.22
T_6	Thiamethoxam 25% WG+ Jaggery @ 0.3 g + 10 g/L	9.97[c]	14.33	816	25316	52841	27525	1 : 2.08
T_7	Untreated control	8.72[d]	-	-	24500	46587	22087	1 : 1.90

Note: Market price of pigeonpea : Rs.5300 per quintal; Cost of production of pigeonpea : Rs. 24500 per hectare.

two punch against pests by combining contact and ingestion activities; Lambda-cyhalothrin: interferes with the nervous system. Chlorantraniliprole: Acts through ingestion, contact, ovicidal and ovi-larvicidal activity. The findings are comparable with works of Regupathy and Sathyaseelan (2011). They mentioned Ampligo 150 ZC - Chlorantraniliprole 100 g/L (10% w/v) + Lambda-cyhalothrin 50 g/L (5% w/v), a new insecticide of the anthranilic diamide + pyrethroid class had showed considerable levels of toxicity to many lepidopteron targets globally. Bajya *et al*. (2015) concluded Ampligo 150 ZC @ 60 g a.i./ ha, which was comparable to Ampligo 150 ZC @ 45 g a.i./ ha had the lowest population of *H. armigera* in cotton.

Thiamethoxam 25% WG + Jaggery reported the most pod damage, while all treatments were found superior over control. Reddy and Paul (2019) reported that Chlorantraniliprole 9.30% + Lamda-cyhalothrin 04.60% ZC was shown to be superior in decreasing pod damage caused by *M. vitrata* in cowpea. The current results are consistent with their findings. Bajya *et al*. (2015) reported at 14 DAS, Ampligo 150 ZC at 60 g a.i./ha (14.33%) had the least square damage among the various insecticides evaluated against cotton bollworms.

Effect of insecticides on yield and economics of pigeonpea

Significantly highest grain yield (14.62 q/ha) was recorded by Isocycloserum 10% DC followed by Chlorantraniliprole 9.30% + Lamda-cyhalothrin 4.60% ZC, Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD and Emamectin benzoate 5% + Lufenuron 40% WG, which were on par with each other. Thiamethoxam 25% WG + Jaggery was shown to be a less successful treatment, recording a lower yield of 9.97 quintal per ha. Isocycloserum 10% DC recorded highest BC ratio of 1:2.63, whereas lowest BC ratio of 1:2.08 was recorded by Thiamethoxam 25% WG + Jaggery (Table 7).

The present findings are in close agreement with the reports of Swami and Ameta (2017) that the spray of Chlorantraniliprole 9.6% + Lambda cyhalothrin 4.6% at 300 mL/ha during *kharif* 2011 and 2012, respectively, resulted in the maximum pigeon pea seed yields of 9.50 and 10.78 quintal per ha. According to Chinwada *et al*. (2023) Ampligo insecticide on seed treatment and spray for the management of fall army worm *Spodoptera frugiperda* in maize had a positive and favourable cost-benefit ratio.

Conclusion

Isocycloserum 10% DC @ 1.25 mL/L greatly outperformed other more recent pesticides in terms of detecting the lowest incidence of pod damage from both borers and pod fly in field conditions. For pod borers, Emamectin benzoate 5% + Lufenuron 40% WG @ 0.15 g/L and Chlorantraniliprole 9.30% + Lamda-cyhalothrin

4.60% ZC @ 0.40 mL/L were the next-best treatments. The next two most effective treatments for pod fly were Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60% ZC @ 0.40 mL/L and Thiamethoxam 25 % WG + Jaggery (0.3 g + 10 g).

Isocycloserum 10% DC (14.56 q/ha) had the highest grain output followed by Chlorantraniliprole 9.30 % + Lamda-cyhalothrin 4.60% ZC (13.05 q/ha). Isocycloserum 10% DC (47,658 Rs/ha) and Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD (42,274 Rs/ha) had the highest net returns. Isoycloserum 10 % DC recorded the highest BC ratio of 1:2.63.

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