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Bio-efficacy of different ready-mix insecticides against pod fly, *Melanagromyza obtusa* Malloch infesting pigeonpea

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ABSTRACT

Pigeonpea pod fly is a major pest that inflicts severe yield losses by damaging seeds concealed within the pods. Its hidden larval feeding makes it difficult to manage. The maggots feed silently inside pods and seeds, thereby diminishing both seed quality and quantity. To address this issue, the bio-efficacy of different ready-mix insecticides against pod fly, Melanagromyza obtusa Malloch, infesting pigeonpea was evaluated in a field experiment conducted during Kharif, 2022-23 and 2023-4 at the Agricultural Research Station, Anand Agricultural University, Derol, Gujarat, India. The population of maggot, pupa, per cent pod damage, and seed damage were found considerably reduced in the plot treated with chlorantraniliprole 8.80% + thiamethoxam 17.50% SC and it was at par with indoxacarb 14.50% + acetamiprid 7.70% SC and emamectin benzoate 5% + lufenuron 40% WG. Significantly higher seed yield was obtained in the treatment of chlorantraniliprole 8.80% + thiamethoxam 17.50% SC and it was at par with indoxacarb 14.50% + acetamiprid 7.70% SC and emamectin benzoate 5% + lufenuron 40% WG. The highest net realization (₹ 62,025/ha) was obtained from the plots treated with chlorantraniliprole 8.80% + thiamethoxam 17.50% SC followed by indoxacarb 14.50% + acetamiprid 7.70% SC (₹ 57,525/ha), emamectin benzoate 5% + lufenuron 40% WG (₹ 53,693/ha) while the highest ICBR of neem seed kernel extract 5 per cent was recorded.

Keywords: *Pigeonpea, ready-mix insecticides, pod fly, Melanagromyza obtusa, Seed damage.*

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millspaugh], commonly known as red gram, *Tur*, *Arhar*, *etc.*, is an erect and short-lived perennial shrub legume (Sharma *et al.*, 2010) and one of the most important pulse crops. It is a versatile crop grown primarily as a vegetable and a multi-use green crop (dhal) in India. It contains (20-22%) protein, (1.2%) fat, (65%) carbohydrates and (3.8%) ash (Aykroyd & Doughty, 1982). According to Kandhare (2014), it also contains higher quality fiber (7g/100g of seeds) as well as thiamin (0.45 mg), niacin (2-9 mg), and riboflavin (0.19 mg). In India, it is cultivated in the area of 41.31 lakh hectares, while its production is 34.17 lakh tonnes and productivity is 827 kg/hectare (Anonymous, 2024). The area under pigeonpea cultivation in Gujarat is 2.64 lakh hectares, whereas its production is 2.27 lakh tonnes with a productivity of 1163 kg/hectare (Anon., 2024). Pigeonpea is generally attacked by more than 300 species of insect- pests and this lead to an approximate economic loss in yield of 15 per cent worth $2285.29 million (Dhaliwal *et al.*, 2015). Among many of the insect-pests, the pod borers, *Maruca vitrata* (Geyer), *Exelastis atomosa* (Wals.), *Lampides boeticus* (L.), *Helicoverpa armigera* (Hubner) and *Melanagromyza obtusa* (Malloch), on the pigeonpea are of major importance (Srilaxmi and Paul, 2010; Sharma, 2016). Among these pests, pod fly, *M. obtusa* is a key pest of pigeonpea throughout South-east Asia. As an internal feeder, the pod fly completes both its maggot and pupal stages within the pods. The maggots consume the developing seeds and undergo pupation inside the same pod. Externally, infested pods typically exhibit no visible signs of damage until the mature maggot bores through the pod wall, leaving behind a thin, papery layer known as a "window," through which the adult flies emerge. It is considered as one of the most destructive pests of pigeonpea across South-East Asia, with seed damage ranging between 20 to 80 per cent (Subharani and Singh, 2009). It alone causes a yield loss of 60 to 80 per cent, and the losses have been estimated at US $ 256 million annually (Patange and Chiranjeevi, 2017). To manage this notorious pest, farmers mainly rely on chemical insecticides. Regular and indiscriminate use of conventional chemical insecticides may lead to the development of insecticide resistance in target pests, pest resurgence, secondary pest outbreaks, environmental pollution and residual toxicity. Therefore, the present experiment was conducted to evaluate the efficacy of different ready-mix insecticides against pod fly, *M. obtusa* infesting pigeonpea.

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MATERIALS AND METHODS

A field study was conducted at Agricultural Research Station, Anand Agricultural University, Derol (Gujarat) India, to evaluate the efficacy of different ready-mix insecticides against pod fly, *M. obtusa* infesting pigeonpea during *Kharif*, 2022-23 and 2023-24. The experiment was laid out in a randomized block design with ten treatments and three replications, using the pigeonpea variety AGT 2. The crop was sown in mid-July with a spacing of 90 × 20 cm. The gross plot size was 4.5 × 5.0 m, while the net plot size measured 2.7 × 4.6 m. The crop was raised using all agronomic practices. Emamectin benzoate 5% + lufenuron 40% WG, chlorantraniliprole 8.80% + thiamethoxam 17.50% SC, diafenthiuron 47% + bifenthrin 9.40% SC, flubendiamide 8.33% + deltamethrin 5.56% SC, imidacloprid 6% + lambda cyhalothrin 4% SL, indoxacarb 14.50% + acetamiprid 7.70% SC, chlorpyriphos 50% + cypermethrin 5% EC, profenofos 40% + cypermethrin 4% EC, pyriproxyfen 5% + fenpropathrin 15% EC were evaluated along with untreated control. The first spray was applied at 50 per cent pod setting and second spray was applied at 15 days after first spray. Spraying was carried out with the help of a knapsack sprayer fitted with a hollow cone nozzle. The observations on the pod and seed damage due to pod fly was recorded from five randomly selected plants per net plot before spray as well as 3, 7 and 14 days after each spray. Then after 5 pods were randomly collected from each plant and were observed for the presence of maggots and pupae of pod fly. The observations on healthy and damage pods as well as healthy and damaged seeds were also recorded at harvest. The yield was recorded from each net plot. Square root transformation was applied to the data on maggot and pupal population analysis. The data on pod and seed damage were subjected to analysis of variance (ANOVA) after arcsine transformation (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Maggot: The data on the efficacy of different ready-mix insecticides against maggot of pod fly, *M. obtusa* infesting pigeonpea are given in Table 1. The data on pooled over periods, sprays and years (*Kharif*, 2022-23 and 2023-24) indicated that the chlorantraniliprole 8.80% + thiamethoxam 17.50% SC (0.09 maggot/pod), indoxacarb 14.50% + acetamiprid 7.70% SC (0.11 maggot/pod) and emamectin benzoate 5% + lufenuron 40% WG (0.13 maggot/pod) were found highly effective to reduced maggot population of pod fly and remained at par with each other. The next best treatments was profenofos 40% + cypermethrin 4% EC (0.37 maggot/pod). The present findings are supported by Chaudhari (2016) who reported that indoxacarb 14.5% + acetamprid 7.7% SC effective insecticides against maggots population of pod fly. Harshita *et al.* (2024) reported that emamectin benzoate 5% + lufenuron 40% WG, 0.15 g/L highly effective against pod fly incidence. Earlier, very limited work has been done on the efficacy of ready-mix insecticides against pod fly and therefore individual insecticides that are components of these ready-mix formulation have been discussed here. Dadas *et al.* (2019) found that chlorantraniliprole 18.5% SC most promising treatment to minimize the maggot population of *M. obtusa.* Veeranna *et al.* (2024) reported that thiamethoxam 25% WG is significantly more effective in reducing the pod fly population. Premkumari *et al.* (2019) and Nithish and Rana (2019) reported that acetamiprid 20% SP found most effective for reducing maggot population of *M. obtusa.* Prakash *et al.* (2021) also reported that emamectin benzoate 5% + lufenuron 40% WG at 60 and 70 g/ha recorded the lowest larval population of *M. vitrata* infesting pigeonpea.

Pupa: The data on the efficacy of different ready-mix insecticides against pupa of pod fly, *M. obtusa* infesting pigeonpea are given in Table 2. The data pertaining to pooled over periods, sprays and years (*Kharif*, 2022-23 and 2023-24) indicated that the chlorantraniliprole 8.80% + thiamethoxam 17.50% SC (0.06 pupa/pod) and remained at par with indoxacarb 14.50% + acetamiprid 7.70% SC (0.07 pupa/pod) and emamectin benzoate 5% + lufenuron 40% WG (0.08 pupa/pod). The next best treatment was profenofos 40% + cypermethrin 4% EC (0.29 pupa/pod). Earlier, Chaudhari (2016) reported that indoxacarb 14.5% + acetamprid 7.7% SC effective insecticides against pupal incidence of pod fly. As information on the bio-efficacy of the ready-mix formulations chlorantraniliprole 8.80% + thiamethoxam 17.50% SC, indoxacarb 14.50% + acetamiprid 7.70% SC and emamectin benzoate 5% + lufenuron 40% WG against pod fly in pigeonpea is currently unavailable, therefore the efficacy of their sole active ingredients reported by various researchers are discussed here under. Chiranjeevi and Sarnaik (2017) revealed that the application of chlorantraniliprole 18.5 SC, 30 g a.i./ha was found most effective in managing pupal population of *M. obtusa.* Bantewad *et al.* (2018) found that the sequential application of chlorantraniliprole, indoxacarb and acetamiprid reduced the population of *M. obtusa.* Vidya *et al.* (2024) reported that acetamiprid 20% SP was significantly effective in diminishing the pupal population of pod fly. Harshita *et al.* (2024) recorded emamectin benzoate 5% + lufenuron 40% WG as highly effective against incidence of pod fly. Hence, present findings are in consistent with the outcomes of previous studies.

Pod damage: The data on the efficacy of different ready-mix insecticides against pod damage due to pod fly, *M. obtusa* in pigeonpea are given in Table 3. Based on pooled over years data (*Kharif*, 2022-23 and 2023-24) indicated that the chlorantraniliprole 8.80% + thiamethoxam 17.50% SC treated plot registered significantly the lowest per cent pod damage (8.04%) and it was remained at par with indoxacarb 14.50% + acetamiprid 7.70% SC (8.22%) and emamectin benzoate 5% + lufenuron 40% WG (8.92%). The present findings are in accordance with the work done by Chaudhari (2016) who reported that indoxacarb 14.5% + acetamprid 7.7% SC was found effective insecticides against pod damage due to pod fly. Harshita *et al.* (2024) reported that emamectin benzoate 5% + lufenuron 40% WG is highly effective against per cent pod damage due to pod fly. The next best treatment was profenofos 40% + cypermethrin 4% EC with 14.67 per cent pod damage and it was at par with imidacloprid 6% + lambda cyhalothrin 4% SL (13.83%) and flubendiamide 8.33% + deltamethrin 5.56% SC (14.96%). Due to the limited research available in public domain on the efficacy of ready-mix insecticides, chlorantraniliprole 8.80% + thiamethoxam 17.50% SC, indoxacarb 14.50% + acetamiprid 7.70% SC and emamectin benzoate 5% + lufenuron 40% WG against pod fly, discussion has been made here on the individual insecticides that are components of these ready-mix formulations. Veeranna *et al.* (2024) reported that thiamethoxam 25% WG significantly more effective in reducing per cent pod damage due to pod fly. Premkumari *et al.* (2019) reported that acetamiprid 20% SP found most effective for reducing per cent pod damage of *M. obtusa.* Bantewad *et al.* (2018) found that sequential application of chlorantraniliprole, indoxacarb and acetamiprid reduced the pod damage caused by *M. obtusa.* Sravanthi *et al.* (2023) revealed that chlorantraniliprole 18.5% SC significantly reduced the per cent pod damage (11.63%) caused by pod fly. Vidya *et al.* (2024) reported that acetamiprid 20% SP was significantly effective for reducing the pod damage caused pod fly.

Seed damage: The data on the seed damage due to *M. obtusa* are given in Table 4. The data on pooled over years (*Kharif*, 2022-23 and 2023-24) indicated that the chlorantraniliprole 8.80% + thiamethoxam 17.50% SC treated plot registered significantly the lowest per cent seed damage (12.56%) and it was remained at par with indoxacarb 14.50% + acetamiprid 7.70% SC (13.07%) and emamectin benzoate 5% + lufenuron 40% WG (13.69%). The present results are in conformity with the findings of Chaudhari (2016) who reported that indoxacarb 14.5% + acetampridd 7.7% SC effective insecticides against seed damage due to pod fly. As information on the bio-efficacy of the ready-mix formulations chlorantraniliprole 8.80% + thiamethoxam 17.50% SC, indoxacarb 14.50% + acetamiprid 7.70% SC and emamectin benzoate 5% + lufenuron 40% WG against pod fly in pigeonpea is currently unavailable, therefore, the efficacy of their sole active ingredients reported by earlier researchers have been discussed. Veeranna *et al.* (2024) reported that thiamethoxam 25% WG is significantly more effective in reducing the per cent seed damage due to pod fly. Keval *et al.* (2016) and Premkumari *et al.* (2019) reported that acetamiprid 20% SP found effective for reducing seed damage of *M. obtusa.* Sravanthi *et al.* (2023) found that chlorantraniliprole 18.5% SC significantly reduced the seed damage caused by pod fly. Vidya *et al.* (2024) reported that acetamiprid 20% SP was significantly effective for diminishing the seed damage caused pod fly. Sonune and Bhamare (2018) reported that significantly lowest grain damage due to pod fly infesting pigeonpea recorded in the treatment emamectin benzoate 0.002%. Thus, the present findings are in close agreement with those reported by earlier researchers.

Seed yield: The data on the impact of ready-mix insecticides on seed yield of pigeonpea are presented in Table 5. The based on pooled data analysis results revealed that the significantly higher seed yield (1979 kg/ha) recorded in plot treated with chlorantraniliprole 8.80% + thiamethoxam 17.50% and it was remained at par with indoxacarb 14.50% + acetamiprid 7.70% SC (1915 kg/ha) and emamectin benzoate 5% + lufenuron 40% WG (1860 kg/ha).

Economics: Economics of different insecticides evaluated against pod fly of pigeonpea presented in Table 6 indicated that the highest (₹ 62,025/ha) net realization was obtained from the plots treated with chlorantraniliprole 8.80% + thiamethoxam 17.50% SC followed by indoxacarb 14.50% + acetamiprid 7.70% SC (₹ 57,525/ha), emamectin benzoate 5% + lufenuron 40% WG (₹ 53,693/ha), profenofos 40% + cypermethrin 4% EC (₹ 34,802/ha), imidacloprid 6% + lambda cyhalothrin 4% SL (₹ 29,120/ha), flubendiamide 8.33% + deltamethrin 5.56% SC (₹ 27,983/ha), chlorpyriphos 50% + cypermethrin 5% EC (₹ 21,886/ha), diafenthiuron 47% + bifenthrin 9.40% SC (₹ 19,623/ha) and pyriproxyfen 5% + fenpropathrin 15% EC (₹ 18,448/ha). Looking to the ICBR, the maximum (1: 7.63) return was obtained with the treatment of indoxacarb 14.50% + acetamiprid 7.70% SC followed by emamectin benzoate 5% + lufenuron 40% WG (1: 6.47), chlorantraniliprole 8.80% + thiamethoxam 17.50% (1: 5.76), imidacloprid 6% + lambda cyhalothrin 4% SL (1: 5.62), profenofos 40% + cypermethrin 4% EC (1: 4.52), flubendiamide 8.33% + deltamethrin 5.56% SC (1: 4.31), diafenthiuron 47% + bifenthrin 9.40% SC (1: 2.71), chlorpyriphos 50% + cypermethrin 5% EC (1: 3.53) and pyriproxyfen 5% + fenpropathrin 15% EC (1: 3.19).

Table 1: Efficacy of ready-mix insecticides against maggot of pod fly, M. obtusa in pigeonpea (Pooled: 2022-23 and 2023-24)

Tr. No	Treatment	Conc. (%)	No. of maggot/pod								
			2022-23				2023-24				Pooled over years
			Before spray	1st spray	2nd spray	Pooled over sprays	Before spray	1st spray	2nd spray	Pooled over sprays	
T_1	Emamectin benzoate 5% + Lufenuron 40% WG	0.005	1.01	0.79^{a}	0.78^{a}	0.79^{a}	1.04	0.81^{a}	0.79^{a}	0.80^{a}	0.79^{a}
			(0.53)	(0.13)	(0.11)	(0.12)	(0.58)	(0.15)	(0.12)	(0.13)	(0.13)
T_2	Chlorantraniliprole 8.80% + Thiamethoxam 17.50% SC	0.031	1.03	0.77^{a}	0.76^{a}	0.76^{a}	1.04	0.80^{a}	0.76^{a}	0.78^{a}	0.77^{a}
			(0.55)	(0.09)	(0.07)	(0.08)	(0.58)	(0.14)	(0.08)	(0.11)	(0.09)
T_3	Diafenthiuron 47% + Bifenthrin 9.40% SC	0.059	1.02	0.95^{b}	0.99^{b}	0.97^{bc}	1.03	0.98^{b}	1.01^{b}	0.99^{bc}	0.98^{cd}
			(0.54)	(0.41)	(0.47)	(0.44)	(0.57)	(0.46)	(0.51)	(0.49)	(0.46)
T_4	Flubendiamide 8.33% + Deltamethrin 5.56% SC	0.006	1.02	0.94^{b}	0.95^{b}	0.94^{bc}	1.04	0.96^{b}	0.95^{b}	0.96^{bc}	0.95^{bc}
			(0.54)	(0.38)	(0.40)	(0.39)	(0.59)	(0.42)	(0.41)	(0.41)	(0.40)
T_5	Imidacloprid 6% + Lambda cyhalothrin 4% SL	0.005	1.03	0.93^{b}	0.94^{b}	0.93^{b}	1.03	0.95^{b}	0.94^{b}	0.95^{bc}	0.94^{bc}
			(0.55)	(0.36)	(0.38)	(0.37)	(0.57)	(0.41)	(0.39)	(0.40)	(0.38)
T_6	Indoxacarb 14.50% + Acetamiprid 7.70% SC	0.019	1.01	0.78^{a}	0.77^{a}	0.77^{a}	1.04	0.80^{a}	0.77^{a}	0.79^{a}	0.78^{a}
			(0.53)	(0.11)	(0.09)	(0.10)	(0.58)	(0.14)	(0.10)	(0.12)	(0.11)
T_7	Chlorpyriphos 50% + Cypermethrin 5% EC	0.092	1.04	0.94^{b}	0.97^{b}	0.96^{bc}	1.03	0.97^{b}	1.00^{b}	0.98^{bc}	0.97^{bcd}
			(0.58)	(0.39)	(0.45)	(0.42)	(0.57)	(0.44)	(0.49)	(0.47)	(0.44)
T_8	Profenofos 40% + Cypermethrin 4% EC	0.110	1.01	0.92^{b}	0.93^{b}	0.93^{b}	1.03	0.95^{b}	0.93^{b}	0.94^{b}	0.93^{b}
			(0.53)	(0.35)	(0.36)	(0.36)	(0.57)	(0.40)	(0.37)	(0.38)	(0.37)
T_9	Pyriproxyfen 5% + Fenpropathrin 15% EC	0.025	1.03	0.97^{b}	0.99^{b}	0.98^{c}	1.04	0.99^{b}	1.02^{b}	1.01^{c}	0.99^{d}
			(0.56)	(0.44)	(0.48)	(0.46)	(0.58)	(0.48)	(0.54)	(0.51)	(0.49)
T_{10}	Untreated control	-	1.01	1.11^{c}	1.18^{c}	1.15^{d}	1.03	1.14^{c}	1.20^{c}	1.17^{d}	1.16^{e}
			(0.51)	(0.74)	(0.90)	(0.82)	(0.57)	(0.80)	(0.95)	(0.87)	(0.85)
S. Em.±	Treatment (T)		0.05	0.03	0.03	0.02	0.05	0.03	0.03	0.02	0.01
	Period (P)		--	0.02	0.02	0.01	--	0.01	0.02	0.01	0.01
	Spray (S)		--	--	--	0.01	--	--	--	0.01	0.01
	Year (Y)		--	--	--	--	--	--	--	--	0.01
	T x P		--	0.04	0.05	0.03	--	0.05	0.05	0.03	0.02
	T x S		--	--	--	0.03				0.03	0.02
	T x Y		--	--	--	--				--	0.01
	P x S		--	--	--	0.01				0.01	0.01
	Y x P		--	--	--	--					0.01
	Y x S		--	--	--	-					0.03
	T x P x S		--	--	--	0.04				0.05	0.03
	T x P x Y		--	--	--	--					0.03
	T x S x Y		--	--	--	--					0.01
	S x P x Y		--	--	--	--					0.01
	T x P x S x Y		--	--	--	--	--	--	--	--	0.04

C. D. at 5% T		NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	Sig
C. V. %		8.20	7.56	8.81	8.20	8.06	8.38	8.59	8.42	8.31
Note:	(i) Figures outside parenthesis are $\sqrt{x+0.5}$ transformed value and those inside parenthesis are retransformed values. (ii) Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance. (iii) DAS: Day after spraying, NS- Non-Significant, Sig.- Significant (iv) Significant parameters and its interactions: T and P									

Table 2: Efficacy of ready-mix insecticides against pupa of pod fly, M. obtusa in pigeonpea (Pooled: 2022-23 and 2023-24)

Tr. No	Treatment	Conc. (%)	No. of pupa/pod								
			2022-23				2023-24				Pooled over years
			Before spray	1st spray	2nd spray	Pooled over sprays	Before spray	1st spray	2nd spray	Pooled over sprays	
T_1	Emamectin benzoate 5% + Lufenuron 40% WG	0.005	0.92	0.78^{a}	0.73^{a}	0.75^{a}	0.92	0.79^{a}	0.75^{a}	0.77^{a}	0.76^{a}
			(0.35)	(0.11)	(0.03)	(0.07)	(0.35)	(0.12)	(0.07)	(0.09)	(0.08)
T_2	Chlorantraniliprole 8.80% + Thiamethoxam 17.50% SC	0.031	0.90	0.76^{a}	0.72^{a}	0.74^{a}	0.92	0.78^{a}	0.74^{a}	0.76^{a}	0.75^{a}
			(0.32)	(0.07)	(0.01)	(0.04)	(0.35)	(0.10)	(0.05)	(0.08)	(0.06)
T_3	Diafenthiuron 47% + Bifenthrin 9.40% SC	0.059	0.92	0.92^{b}	0.91^{b}	0.91^{b}	0.94	0.93^{b}	0.94^{b}	0.93^{b}	0.92^{bc}
			(0.34)	(0.34)	(0.33)	(0.33)	(0.38)	(0.36)	(0.38)	(0.37)	(0.35)
T_4	Flubendiamide 8.33% + Deltamethrin 5.56% SC	0.006	0.91	0.90^{b}	0.89^{b}	0.89^{b}	0.93	0.91^{b}	0.91^{b}	0.91^{b}	0.90^{bc}
			(0.34)	(0.31)	(0.29)	(0.30)	(0.36)	(0.32)	(0.33)	(0.33)	(0.31)
T_5	Imidacloprid 6% + Lambda cyhalothrin 4% SL	0.005	0.91	0.90^{b}	0.88^{b}	0.89^{b}	0.93	0.90^{b}	0.90^{b}	0.90^{b}	0.89^{c}
			(0.32)	(0.30)	(0.28)	(0.29)	(0.37)	(0.31)	(0.30)	(0.30)	(0.30)
T_6	Indoxacarb 14.50 % + Acetamiprid 7.70% SC	0.019	0.92	0.77^{a}	0.73^{a}	0.75^{a}	0.91	0.78^{a}	0.74^{a}	0.76^{a}	0.76^{a}
			(0.34)	(0.09)	(0.03)	(0.06)	(0.32)	(0.12)	(0.05)	(0.08)	(0.07)
T_7	Chlorpyriphos 50% + Cypermethrin 5% EC	0.092	0.92	0.91^{b}	0.90^{b}	0.91^{b}	0.94	0.92^{b}	0.93^{b}	0.92^{b}	0.91^{bc}
			(0.35)	(0.33)	(0.31)	(0.32)	(0.37)	(0.34)	(0.36)	(0.35)	(0.34)
T_8	Profenofos 40% + Cypermethrin 4% EC	0.110	0.91	0.89^{b}	0.87^{b}	0.88^{b}	0.93	0.90^{b}	0.89^{b}	0.89^{b}	0.89^{b}
			(0.33)	(0.29)	(0.25)	(0.27)	(0.37)	(0.30)	(0.29)	(0.30)	(0.29)
T_9	Pyriproxyfen 5% + Fenpropathrin 15% EC	0.025	0.94	0.93^{b}	0.93^{b}	0.93^{b}	0.94	0.93^{b}	0.94^{b}	0.94^{b}	0.93^{c}
			(0.38)	(0.37)	(0.36)	(0.36)	(0.39)	(0.37)	(0.39)	(0.38)	(0.37)
T_{10}	Untreated control	-	0.91	1.05^{c}	1.12^{c}	1.09^{c}	0.93	1.07^{c}	1.12^{c}	1.10^{c}	1.09^{d}
			(0.32)	(0.61)	(0.75)	(0.68)	(0.36)	(0.64)	(0.76)	(0.70)	(0.69)
S. Em.±	Treatment (T)		0.05	0.02	0.02	0.02	0.05	0.02	0.02	0.02	0.01
	Period (P)		--	0.01	0.01	0.01	--	0.01	0.01	0.01	0.01
	Spray (S)		--	--	--	0.01	--	--	--	0.01	0.01
	Year (Y)		--	--	--	--	--	--	--	--	0.01
	T x P		--	0.04	0.04	0.03	--	0.04	0.04	0.03	0.02
	T x S		--	--	--	0.02	--	--	--	0.02	0.02
	T x Y		--	--	--	--	--	--	--	--	0.02
	P x S		--	--	--	0.01	--	--	--	0.01	0.01
	Y x P		--	--	--	--	--	--	--	--	0.01
	Y x S		--	--	--	--	--	--	--	--	0.01
	T x P x S		--	--	--	0.04	--	--	--	0.04	0.03
	T x P x Y		--	--	--	--	--	--	--	--	0.03
	T x S x Y		--	--	--	--	--	--	--	--	0.02
	S x P x Y		--	--	--	--	--	--	--	--	0.01
	T x P x S x Y		--	--	--	--	--	--	--	--	0.04
C. D. at 5% T			NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	Sig
C. V. %			9.08	7.53	8.29	7.85	9.82	7.59	8.18	7.83	7.84
Note:	(i) Figures outside parenthesis are $\sqrt{x+0.5}$ transformed value and those inside parenthesis are retransformed values. (ii) Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance. (iii) DAS: Day after spraying, NS- Non-Significant, Sig.- Significant (iv) Significant parameters and its interactions: T and P										

Table 3: Efficacy of ready-mix insecticides against pod damage due to pod fly, M. obtusa in pigeonpea (Pooled: 2022-23 and 2023-24)

Tr. No	Treatment	Conc. (%)	Pod damage (%)								
			2022-23				2023-24				Pooled over years
			Before spray	1st spray	2nd spray	Pooled over sprays	Before spray	1st spray	2nd spray	Pooled over sprays	
T_1	Emamectin benzoate 5% + Lufenuron 40% WG	0.005	11.54	14.80^{a}	18.56^{b}	16.68^{a}	13.17	16.31^{a}	19.84^{a}	18.08^{a}	17.38^{a}
			(4.00)	(6.52)	(10.13)	(8.24)	(5.19)	(7.89)	(11.52)	(9.63)	(8.92)
T_2	Chlorantraniliprole 8.80% + Thiamethoxam 17.50% SC	0.031	11.54	14.68^{a}	16.31^{a}	15.50^{a}	13.17	15.89^{a}	18.99^{a}	17.44^{a}	16.47^{a}
			(4.00)	(6.42)	(7.89)	(7.14)	(5.19)	(7.49)	(10.59)	(8.98)	(8.04)
T_3	Diafenthiuron 47% + Bifenthrin 9.40 % SC	0.059	11.54	20.94^{c}	25.52^{d}	23.23^{c}	11.54	22.81^{c}	26.81^{bc}	24.81^{c}	24.02^{d}
			(4.00)	(12.78)	(18.56)	(15.56)	(4.00)	(15.03)	(20.34)	(17.60)	(16.57)
T_4	Flubendiamide 8.33% + Deltamethrin 5.56% SC	0.006	13.17	19.30^{bc}	24.51^{cd}	21.91^{bc}	11.54	21.37^{bc}	25.84^{bc}	23.60^{bc}	22.76^{bc}
			(5.19)	(10.92)	(17.22)	(13.92)	(4.00)	(13.28)	(18.99)	(16.03)	(14.96)
T_5	Imidacloprid 6% + Lambda cyhalothrin 4% SL	0.005	13.17	18.56^{b}	23.45^{cd}	21.00^{b}	14.80	20.15^{b}	25.18^{bc}	22.66^{b}	21.83^{b}
			(5.19)	(10.13)	(15.83)	(12.85)	(6.52)	(11.87)	(18.10)	(14.85)	(13.83)

T$_6$	Indoxacarb 14.50% + Acetamiprid 7.70% SC	0.019	13.17	13.71^{a}	17.65^{ab}	15.68^{a}	13.17	16.31^{a}	18.99^{a}	17.65^{a}	16.67^{a}
			(5.19)	(5.62)	(9.19)	(7.31)	(5.19)	(7.89)	(10.59)	(9.19)	(8.22)
T$_7$	Chlorpyriphos 50% + Cypermethrin 5% EC	0.092	11.54	19.78^{bc}	24.51^{cd}	22.15^{bc}	13.17	21.70^{bc}	26.11^{bc}	23.91^{bc}	23.03^{cd}
			(4.00)	(11.46)	(17.22)	(14.21)	(5.19)	(13.68)	(19.36)	(16.42)	(15.30)
T$_8$	Profenofos 40% + Cypermethrin 4% EC	0.110	13.17	18.56^{b}	23.14^{c}	20.85^{b}	11.54	20.21^{b}	24.87^{b}	22.54^{b}	21.70^{b}
			(5.19)	(10.13)	(15.44)	(12.67)	(4.00)	(11.93)	(17.69)	(14.69)	(13.67)
T$_9$	Pyriproxyfen 5% + Fenpropathrin 15% EC	0.025	11.54	20.94^{c}	25.49^{d}	23.22^{c}	13.17	22.81^{c}	27.42^{c}	25.11^{c}	24.17^{d}
			(4.00)	(12.78)	(18.51)	(15.54)	(5.19)	(15.03)	(21.21)	(18.01)	(16.76)
T$_{10}$	Untreated control	-	13.17	24.85^{d}	29.83^{e}	27.34^{d}	14.80	26.81^{d}	31.86^{d}	29.34^{d}	28.34^{e}
			(5.19)	(17.65)	(24.74)	(21.09)	(6.52)	(20.34)	(27.87)	(24.00)	(22.53)
S. Em.±	Treatment (T)		1.05	0.69	0.69	0.49	1.41	0.69	0.73	0.50	0.35
	Period (P)		--	0.04	0.38	0.27	--	0.38	0.40	0.27	0.19
	Spray (S)		--	--	--	0.22	--	--	--	0.22	0.16
	Year (Y)		--	--	--	--	--	--	--	--	0.16
	T x P		--	1.19	1.20	0.85	--	1.20	1.27	0.87	0.61
	T x S		--	--	--	0.69	--	--	--	0.71	0.50
	T x Y		--	--	--	--	--	--	--	--	0.50
	P x S		--	--	--	0.38	--	--	--	0.39	0.27
	Y x P		--	--	--	--	--	--	--	--	0.27
	Y x S		--	--	--	-	--	--	--	--	0.22
	T x P x S		--	--	--	1.20	--	--	--	1.23	0.86
	T x P x Y		--	--	--	--	--	--	--	--	0.86
	T x S x Y		--	--	--	--	--	--	--	--	0.70
	S x P x Y		--	--	--	--	--	--	--	--	0.38
	T x P x S x Y		--	--	--	--	--	--	--	--	1.21
C. D. at 5% T			NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	Sig.
C. V. %			14.66	11.06	9.10	10.00	18.74	10.15	8.95	9.44	8.90

Note:
(i) Figures outside parenthesis are arc sign transformed value and those inside parenthesis are retransformed values.
(ii) Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance.
(iii) DAS: Day after spraying, NS- Non-Significant, Sig.- Significant
(iv) Significant parameters and its interactions: T and P

Table 4: Efficacy of ready-mix insecticides against seed damage due to pod fly, M. obtusa in pigeonpea (Pooled: 2022-23 and 2023-24)

Tr. No	Treatment	Conc. (%)	Seed damage (%)								
			2022-23				2023-24				Pooled over years
			Before Spray	1st spray	2nd spray	Pooled over sprays	Before Spray	1st spray	2nd spray	Pooled over sprays	
T$_1$	Emamectin benzoate 5% + Lufenuron 40% WG	0.005	18.65	19.55^{a}	21.98^{a}	20.77^{a}	19.53	21.44^{a}	23.88^{a}	22.66^{a}	21.71^{a}
			(10.23)	(11.20)	(14.01)	(12.57)	(11.18)	(13.36)	(16.39)	(14.85)	(13.69)
T$_2$	Chlorantraniliprole 8.80% + Thiamethoxam 17.50% SC	0.031	18.60	19.22^{a}	21.18^{a}	20.20^{a}	19.29	20.37^{a}	22.26^{a}	21.31^{a}	20.76^{a}
			(10.17)	(10.84)	(13.06)	(11.93)	(10.91)	(12.11)	(14.35)	(13.21)	(12.56)
T$_3$	Diafenthiuron 47 % + Bifenthrin 9.40 % SC	0.059	18.65	23.21^{b}	27.90^{b}	25.56^{b}	20.43	26.49^{b}	30.07^{b}	28.28^{b}	26.92^{bc}
			(10.23)	(15.53)	(21.90)	(18.61)	(12.19)	(19.90)	(25.10)	(22.45)	(20.49)
T$_4$	Flubendiamide 8.33% + Deltamethrin 5.56% SC	0.006	19.25	22.78^{b}	27.18^{b}	24.98^{b}	19.62	25.87^{b}	29.47^{b}	27.67^{b}	26.32^{bc}
			(10.87)	(15.00)	(20.86)	(17.83)	(11.27)	(19.04)	(24.20)	(21.56)	(19.67)
T$_5$	Imidacloprid 6% + Lambda cyhalothrin 4% SL	0.005	18.52	22.59^{b}	27.10^{b}	24.84^{b}	19.60	25.44^{b}	28.61^{b}	27.03^{b}	25.94^{b}
			(10.09)	(14.75)	(20.75)	(17.65)	(11.25)	(18.46)	(22.93)	(20.65)	(19.13)
T$_6$	Indoxacarb 14.50% + Acetamiprid 7.70% SC	0.019	18.39	19.41^{a}	21.41^{a}	20.41^{a}	19.89	20.90^{a}	23.07^{a}	21.98^{a}	21.20^{a}
			(9.95)	(11.04)	(13.33)	(12.16)	(11.58)	(12.72)	(15.35)	(14.01)	(13.07)
T$_7$	Chlorpyriphos 50% + Cypermethrin 5% EC	0.092	18.92	22.96^{b}	27.42^{b}	25.19^{b}	19.83	26.11^{b}	29.67^{b}	27.89^{b}	26.54^{bc}
			(10.51)	(15.22)	(21.21)	(18.12)	(11.50)	(19.37)	(24.50)	(21.88)	(19.97)
T$_8$	Profenofos 40% + Cypermethrin 4% EC	0.110	19.68	22.59^{b}	26.78^{b}	24.69^{b}	20.46	25.36^{b}	28.74^{b}	27.05^{b}	25.87^{b}
			(11.34)	(14.76)	(20.31)	(17.45)	(12.22)	(18.34)	(23.12)	(20.68)	(19.04)
T$_9$	Pyriproxyfen 5% + Fenpropathrin 15% EC	0.025	19.01	23.29^{b}	28.19^{b}	25.74^{b}	19.81	26.72^{b}	30.72^{b}	28.72^{b}	27.23^{c}
			(10.61)	(15.64)	(22.32)	(18.86)	(11.49)	(20.21)	(26.10)	(23.09)	(20.94)
T$_{10}$	Untreated control	-	19.80	26.66^{c}	32.65^{c}	29.65^{c}	20.72	30.40^{c}	36.17^{c}	33.29^{c}	31.47^{d}
			(11.47)	(20.13)	(29.10)	(24.48)	(12.52)	(25.61)	(34.83)	(30.12)	(27.25)
S. Em.±	Treatment (T)		1.48	0.64	0.79	0.51	1.19	0.70	0.96	0.59	0.39
	Period (P)		--	0.35	0.43	0.28	--	0.39	0.53	0.32	0.21
	Spray (S)		--	--	--	0.23	--	--	--	0.26	0.17
	Year (Y)		--	--	--	--	--	--	--	--	0.47
	T x P		--	1.11	1.37	0.88	--	1.22	1.66	1.02	0.68
	T x S		--	--	--	0.72	--	--	--	0.84	0.55
	T x Y		--	--	--	--	--	--	--	--	0.55
	P x S		--	--	--	0.39	--	--	--	0.46	0.30
	Y x P		--	--	--	--	--	--	--	--	0.30
	Y x S		--	--	--	-	--	--	--	--	0.25
	T x P x S		--	--	--	1.25	--	--	--	1.45	0.96
	T x P x Y		--	--	--	--	--	--	--	--	0.96
	T x S x Y		--	--	--	--	--	--	--	--	0.78
	S x P x Y		--	--	--	--	--	--	--	--	0.43
	T x P x S x Y		--	--	--	--	--	--	--	--	1.35
C. D. at 5% T			NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	Sig.

C. V. %	13.51	8.64	9.04	8.92	10.32	8.46	10.20	9.43	9.21

Note:	(i) Figures outside parenthesis are arc sign transformed value and those inside parenthesis are retransformed values. (ii) Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance. (iii) DAS: Day after spraying, NS- Non-Significant, Sig.- Significant (iv) Significant parameters and its interactions: T and P

Table 5: Impact of ready-mix insecticides on seed yield of pigeonpea

Tr. No.	Treatments	Conc. (%)	Seed yield (kg/ha)		
			2022-23	2023-24	Pooled
1	Emamectin benzoate 5% + Lufenuron 40% WG	0.005	1877[ab]	1843[ab]	1860[a]
2	Chlorantraniliprole 8.80% + Thiamethoxam 17.50% SC	0.031	2011[a]	1947[a]	1979[a]
3	Diafenthiuron 47% + Bifenthrin 9.40% SC	0.059	1405[c]	1342[c]	1373[c]
4	Flubendiamide 8.33% + Deltamethrin 5.56% SC	0.006	1498[c]	1487[c]	1493[bc]
5	Imidacloprid 6% + Lambda cyhalothrin 4% SL	0.005	1520[c]	1499[c]	1509[bc]
6	Indoxacarb 14.50% + Acetamiprid 7.70% SC	0.019	1945[a]	1884[a]	1915[a]
7	Chlorpyriphos 50% + Cypermethrin 5% EC	0.092	1454[c]	1357[c]	1406[c]
8	Profenofos 40% + Cypermethrin 4% EC	0.110	1617[bc]	1563[bc]	1590[b]
9	Pyriproxyfen 5% + Fenpropathrin 15% EC	0.025	1393[c]	1320[c]	1357[c]
10	Untreated control	-	1138[d]	1047[d]	1093[d]
S. Em. ±	Treatment (T)		82.93	88.38	54.56
	Year (Y)		-	-	27.10
	T × Y		-	-	85.70
C. D. at 5% T			Sig.	Sig.	Sig.
C. V. %			9.06	10.01	9.53

Note:	(i) Treatment means with the letter(s) in common are not significantly differed by DNMRT at 5% level of significance (ii) Sig.- Significant (iii) Significant parameters and its interactions: T

Table 6: Economics of different ready-mix insecticides evaluated against pod fly, M. obtusa infesting pigeonpea

Tr. No.	Treatments	Conc. (%)	Quantity of insecticides required for two spray (kg or L/ha)	Price of insecticides (₹/ kg or litre)	Cost of insecticides required for two spray (₹/ha)	Labour cost for two spray (₹/ha)	Total cost of plant protection (₹/ha)	Seed yield (kg/ha)	Net gain (yield) over untreated control (kg/ha)	Net realization (₹/ha)	ICBR
1.	Emamectin benzoate 5% + Lufenuron 40% WG	0.005	0.12	39958	4795	3504	8299	1860	767	53693	1 : 6.47
2.	Chlorantraniliprole 8.80% + Thiamethoxam 17.50% SC	0.031	1.43	5100	7271	3504	10775	1979	886	62025	1 : 5.76
3.	Diafenthiuron 47% + Bifenthrin 9.40% SC	0.059	1.25	2979	3725	3504	7229	1373	280	19623	1 : 2.71
4.	Flubendiamide 8.33% + Deltamethrin 5.56% SC	0.006	0.54	5540	2992	3504	6496	1493	400	27983	1 : 4.31
5.	Imidacloprid 6% + Lambda cyhalothrin 4% SL	0.005	0.60	2800	1680	3504	5184	1509	416	29120	1 : 5.62
6.	Indoxacarb 14.50% + Acetamiprid 7.70% SC	0.019	1.00	4033	4031	3504	7535	1915	822	57525	1 : 7.63
7.	Chlorpyriphos 50% + Cypermethrin 5% EC	0.092	2.00	1350	2701	3504	6205	1406	313	21886	1 : 3.53
8.	Profenofos 40% + Cypermethrin 4% EC	0.110	3.00	1400	4200	3504	7704	1590	497	34802	1 : 4.52
9.	Pyriproxyfen 5% + Fenpropathrin 15% EC	0.025	1.50	1525	2288	3504	5792	1357	264	18448	1 : 3.19
10.	Untreated control	-	-	-	-	-	-	1093	-	-	-

Note:	1.	Labour charges	• Semi skilled labour • Farm labour • Labour charges for one spray • Total labour charge for two sprays	: ₹ 487.00 per day x 2 labour : ₹ 389.00 per day x 2 labour : ₹ 974.00 + ₹ 778.00 : ₹ 1752.00 x 2 sprays	= ₹ 974.00 / ha = ₹ 778.00 / ha = ₹ 1752.00 / ha = ₹ 3504.00 / ha
	2.	Market price of pigeonpea seed = ₹ 70/ kg seeds			

Pigeonpea pod fly is a major pest causing severe yield loss by damaging seeds inside the pods. Its hidden larval feeding and lack of effective resistant varieties make management difficult. The maggots feed inside pods and seeds, making detection difficult. Causes significant reduction in seed quality and quantity.

CONCLUSION

Based on the two years of field experimentation, it can be concluded that chlorantraniliprole 8.80% + thiamethoxam 17.50% SC, indoxacarb 14.50% + acetamiprid 7.70% SC and emamectin benzoate 5% + lufenuron 40% WG were found effective to manage of pod fly, *M. obtusa* by reducing the maggot and pupal population, pod damage and seed damage in pigeonpea. The effect of these treatments had also been reflected in the seed yield of pigeonpea.

FUTURE SCOPE OF THE STUDY

The findings indicate the potential of certain ready-mix insecticides for effective management of pigeonpea pod fly. Future research should focus on integrating these insecticides with eco-friendly approaches such as botanicals, biocontrol agents, physical and cultural practices to develop sustainable IPM strategies.

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CONFLICTING INTERESTS

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