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Bio-Efficacy of Selected Insecticides against Pigeonpea Pod Fly, *Melanagromyza obtusa* (Malloch)

Vidya[1], G. Keshavareddy[2], S. M. Ranjitha[3] and K. S. Jagadish[4]
[1,3&4]Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
[2]AICRP on Pigeonpea, Zonal Agricultural Research Station, UAS, GKVK, Bengaluru - 560 065
e-Mail : keshavaa_reddy@gmail.com

Authors Contribution

Vidya : Investigation, data collection and analysis, original draft preparation;
G. Keshavareddy : Conceptualization, framed research proposal, supervision and draft correction;
S. M. Ranjitha : Data collection;
K. S. Jagadish : Correction of manuscript:

Corresponding Author :
G. Keshavareddy

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Abstract

The bio-efficacy study with different insecticides against pigeonpea pod fly was conducted at the research fields of the Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru to evaluate different insecticides against pod fly, *Melanagromyza obtusa* (Malloch) infesting pigeonpea pods. The results revealed that two sprays of acetamiprid 20% SP @ 0.2 g/l at fifteen days interval starting from 50 per cent flowering stage was found to be the most effective insecticide against pod fly which recorded least per cent pod and grain damage with maximum Incremental Cost Benefit Ratio (12.92). Dinotefuran 20% SG @ 0.3 g/l was also showed similar effectiveness against *M. obtusa*. The next best insecticide treatments were thiacloprid 21.7% SC @ 0.7 ml/l and thiamethoxam 25% WG @ 0.4 g/l + jaggery @ 5 g/l. Spinosad 45% SC @ 0.2 ml/l and lufenuron 5.4% EC @ 1ml/l, observed to be moderately effective against pod fly infestation. Diafenthiuron 50% WP @ 1 g/l, flubendiamide 39.35% SC @ 0.3 ml/l and azadirachtin 0.15% @ 5 ml/l were found to be least effective compared to rest of the insecticidal treatments.

Keywords : Pigeonpea, Pod fly, *Melanagromyza obtusa* (Malloch), Insecticides, Acetamiprid, Dinotefuran

Pigeonpea, *Cajanus cajan* (L.) Millsp. commonly known as tur or arhar or red gram is one of the important protein rich legumes of the semi-arid tropics grown throughout the tropical and subtropical regions of the world. Pigeonpea is damaged by a large number of insect pests (more than 300 species) of which pod borer, *Helicoverpa armigera* (Hübner); legume pod borer, *Maruca vitrata* (Fabricius); spiny pod borer, *Etiella zinckenella* (Treitschke); pod fly, *Melanagromyza obtusa* (Malloch) and the bruchids, *Callasobruchus chinensis* (Linnaeus) causes extensive losses worldwide (Shanower *et al*., 1999). The damage caused by *H. armigera, M. vitrata*, *Clavigralla gibbosa* (Spinola) and *M. obtusa* results in major loss in pigeonpea grain yield in Karnataka. The recent climatic changes have influenced the density of *H. armigera* population in different pulse crops (Honnakerappa *et al.,* 2021). The grain yield losses due to pod fly have been reported in the range of 60-80 per cent in pigeonpea (Durairaj, 1995) with mean pod damage and grain damage of 21 per cent to 38.50 per cent and 12.29 per cent to 19.87 per cent, respectively (Khan *et al*., 2014). Late sown and late maturing varieties are highly vulnerable to the pod fly attack. All the immature stages remain with in the developing pod. Before pupation, the fully grown maggots chew the holes in the pod walls leaving a 'window' through which the flies emerge from the pupae in the pod. The concealed feeding habit causes more loss to the crop without farmer's notice to take up timely management practices (Vidya *et al*., 2022). Farmers are able to notice the damage to the seeds due to pod fly infestation only at later stages of pod development and mainly while threshing the pods after harvesting. This has resulted in low and poor quality grain yield. In recent years, pod fly is becoming an emerging constraint in pigeonpea production. In light of this, it is critical to develop appropriate and effective management approaches so that pod fly damage to this protein-rich pulse crop could be curtailed. Additionally, the information on effectiveness of new insecticides is very scanty. Further, it is also necessary to avoid repeated usage of the less effective insecticides against pod fly, not just to avoid leaving substantial pesticidal residues on treated crops, but also to prevent environmental pollution. In this regard, it is important to know the most effective insecticides against pod fly, so that it can be judiciously managed with minimal number of timely applications.

Material and Methods

Evaluation of different insecticides against pod fly on pigeonpea was carried out during *kharif* seasons of 2019 and 2020 at the Zonal Agricultural Research Station (ZARS), GKVK, Bengaluru. The experiment was laid out in Randomised Block Design with ten treatments including untreated control. Each treatment was replicated three times with individual plots size of 4x5 m. The newly released variety, BRG-3 (by All India Coordinated Research Project on Pigeonpea, Bengaluru) was used for the experiment. The insecticidal treatments were imposed at fifty per cent flowering stage followed by second spray after fifteen days interval. Pod fly infestation in each experimental plot of pigeonpea was considered as uniform at the time of treatments imposition at 50 per cent flowering stage during first spray. The number of maggots/pupae was recorded by destructive sampling method of 100 randomly selected pods from 5 randomly tagged plants per replication 15 days after each spray. Further, the per cent pod and grain damage were also recorded 15 days after second spray. Later the per cent reduction in pod and grain damage by pod fly over control was worked out for each treatment (Henderson and Tilton, 1955). The grain yield was recorded at the time of harvest from each experimental plot and converted to kg/ha. The mean number of seeds and pods infested by *M. obtusa* in pigeonpea was worked out and values were then subjected to single factor Analysis of Variance (ANOVA) using IBM SPSS software. The critical difference (CD) at 5 per cent probability level was used as the test criterion and for comparison.

1. *Pod damage* : The data on damaged and healthy pods from the collected samples was recorded and the per cent pod damage was calculated using the formula,

$$\text{Pod damage (\%)} = \frac{\text{Number of pod fly damaged pods}}{\text{Total number of pods observed (100 pods)}} \times 100$$

2. *Grain damage* : The total number of damaged grains in 100 pods was counted and per cent grain damage was calculated using the formula,

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

Results and Discussion

Results of the studies on the bio-efficacy of insecticides against pod fly conducted during November, 2019 and November 2020 at the Zonal Agricultural Research Station (ZARS), GKVK, Bengaluru are presented in Tables 1 to 3.

Number of Maggots or Pupae Per 100 Pods After First Spray

The results reveals, that prevailing number of maggots or pupae, fifteen days after first spray ranged from 7.67 to 28.67 per 100 pods during 2019. All the insecticides tested were found effective in reducing number of maggots or pupae and superior over control. Among treatments, least number of maggots or pupae per 100 pods was recorded in plots treated with acetamiprid (7.67) which was on par with dinotefuran

TABLE 1

Efficacy of selected insecticides against pigeonpea pod fly, *M. obtusa* during 2019

Treatment	No. of maggots/pupae 15 DAS (per 100 pods)		% pod damage**	Per cent reduction in pod damage over control	% grain damage**	Per cent reduction in grain damage over control	Grain yield (kg/ha)
	First spray*	Second spray*					
Spinosad 45% SC @ 0.2 ml/l	12.67 (3.59) abc	7.33 (2.78) cd	16.67 (24.05) bc	53.27	7.92 (16.28) bc	72.02	2181
Diafenthiuron 50% WP @ 1.0 g/l	15.33 (3.98) bc	7.33 (2.79) cd	21.67 (21.67) cd	39.25	11.52 (19.72) d	59.31	1957
Dinotefuran 20% SG @ 0.3 g/l	8.00 (2.91) a	4.00 (2.11) a	9.67 (18.05) a	72.89	4.17 (11.76) a	85.27	2301
Flubendiamide 39. 35% SC @ 0.3 ml/l	15.67 (4.01) bc	9.33 (3.13) de	22.00 (27.94) cd	38.32	11.81 (20.08) d	58.28	1939
Lufenuron 5.4% EC @ 1.0 ml/l	12.00 (3.53) abc	6.67 (2.67) bcd	17.00 (24.21) bc	52.34	10.58 (18.91) cd	62.63	2038
Thiamethoxam 25%WG @ 0.4 g + Jaggery @ 5.0 g/l	8.67 (3.016) a	4.33 (2.19) ab	12.67 (20.74) ab	64.48	5.92 (14.05) ab	79.09	2232
Acetamiprid 20% SP @ 0.2 g/l	7.67 (2.85) a	4.67 (2.26) ab	10.67 (19.03) a	70.09	5.09 (13.02) ab	82.02	2265
Thiacloprid 21 7% SC @ 0.7 ml/l	10.67 (3.34) ab	6.00 (2.55) abc	14.67 (22.47) ab	58.87	6.15 (14.34) ab	78.28	2197
Azadirachtin 0.15%EC @ 5.0 ml/l	17.33 (4.17) d	10.67 (30.19) d	25.33 (3.34) e	28.99	12.60 (20.71) d	55.49	1827
Control (untreated)	28.67 (5.40) e	38.67 (6.25) f	35.67 (36.65) e	-	28.31 (32.10) e	-	1583
Sem±	0.20	0.23	1.68	-	1.16	-	-
CD at 5%	0.60	0.67	4.98	-	3.43	-	-
CV (%)	9.11	12.12	11.74	-	9.30	-	-

**Values in parentheses are Arc sine transformed. * Values in parentheses are SQRT transformed. DAS- Days After Spray. Values in each column followed by same alphabet(s) are not significantly different

TABLE 2

Efficacy of selected insecticides against pigeonpea pod fly, *M. obtusa* during 2020

Treatment	No. of maggots/pupae 15 DAS (per 100 pods)		% pod damage**	Per cent reduction in pod damage over control	% grain damage**	Per cent reduction in grain damage over control	Grain yield (kg/ha)
	First spray*	Second spray*					
Spinosad 45% SC @ 0.2 ml/l	13.00 (3.67) bc	8.00 (2.91) abcd	11.33 (19.92) a	69.92	9.37 (17.80) ab	72.88	2128
Diafenthiuron 50% WP @ 1.0 g/l	16.33 (4.09) cd	9.33 (3.1) bcd	21.33 (27.44) bc	43.38	13.06 (21.11) bc	62.20	2062
Dinotefuran 20% SG @ 0.3 g/l	9.33 (3.13) ab	4.67 (2.25) a	11.67 (19.84) a	69.02	6.67 (14.90) a	80.69	2185
Flubendiamide 39.35% SC @ 0.3 ml/l	17.33 (4.21) cd	11.00 (3.38) cd	21.67 (27.54) bc	42.47	16.50 (23.94) c	52.24	1987
Lufenuron 5.4% EC @ 1.0 ml/l	13.00 (3.67) bc	7.67 (2.84) abc	15.33 (22.93) ab	59.30	13.26 (22.65) c	61.62	2104
Thiamethoxam 25% WG @ 0.4 g + Jaggery @ 5.0 g/l	9.33 (3.13) ab	7.33 (2.78) abc	12.00 (20.14) a	68.14	9.66 (18.02) ab	72.04	2112
Acetamiprid 20% SP @ 0.2 g/l	8.00 (2.86) a	5.33 (2.35) a	12.33 (20.46) a	67.27	6.80 (14.92) a	80.32	2232
Thiacloprid 21.7% SC @ 0.7 ml/l	11.00 (3.38) ab	5.67 (2.47) ab	12.33 (20.45) a	67.27	9.06 (17.44) ab	73.78	2174
Azadirachtin 0.15% EC @ 5.0 ml/l	19.33 (4.44) d	12.67 (3.62) d	26.00 (30.64) c	30.98	22.74 (28.44) d	34.18	1853
Control (untreated)	31.00 (5.61) e	41.67 (6.49) e	37.67 (37.84) d	-	34.55 (35.99) e	-	1709
Sem±	0.22	0.16	1.27	-	1.0	-	-
CD at 5%	0.67	0.46	3.76	-	2.97	-	-
CV (%)	10.57	9.01	8.73	-	9.58	-	-

**Values in parentheses are Arc sine transformed, * Values in parentheses are SQRT transformed. DAS- Days after spray, Values in each column followed by same alphabet(s) are not significantly different

(8.00) and thiamethoxam + jaggery (8.67). Next best treatment was thiacloprid (10.67) followed by lufenuron (12.00), which was on par with spinosad (12.67), followed by diafenthiuron (15.33) which was on par with flubendiamide (15.67). Among all the insecticides tested, azadirachtin was found to be the least effective (17.33) in reducing the maggot or pupal population (Table 1).

The results on the efficacy of selected insecticides against pod fly, *M. obtusa* infesting pigeonpea crop during 2020 are presented in Table 2. Data on number of maggots or pupae per 100 pods, fifteen days after first spray showed significant difference among the treatments. Out of nine insecticide treatments, acetamiprid (8.00) was the best treatment and recorded the lowest maggot or pupal population. Dinotefuran and thiamethoxam + jaggery were found equally effective in reducing pod fly infestation and recorded similar number of maggots or pupae (9.33) followed by thiacloprid (11.00). Spinosad and lufenuron were the next best effective treatments and were on par with each other and recorded the same mean number of maggot or pupae (13.00). The next best treatments against pod fly infestation were diafenthiuron (16.33) and flubendiamide (17.33) and were on par. Azadirachtin was the least effective treatment against pod fly however was significantly superior over untreated control.

At fifteen days after first spray (pooled data; Table 3), it was found that all the nine treatments were found significantly superior over untreated control by recording less number of maggots or pupae of pod fly in treated plots. Acetamiprid (7.83) and dinotefuran (8.67) were the best treatments in reducing the pod fly infestation and were on par with thiamethoxam + jaggery (9.00) followed by thiacloprid (10.83). The next best treatments which recorded less number of maggots or pupae were lufenuron (12.50) and spinosad (12.83) and were found on par with each other. Diafenthiuron (15.83) and flubendiamide (16.50) were the next best treatments which were on par with each other. Azadirachtin (18.33) was the least effective insecticide in reducing number of maggot or pupal population but was found significantly superior over the control (29.83).

Number of Maggots or Pupae Per 100 Pods After Second Spray

Fifteen days after second application of the insecticides, very less mean number of maggots or pupae per 100 pods were noticed in dinotefuran treatment (4.00) and it was closely followed by thiamethoxam + jaggery (4.33) which was on par with acetamiprid (4.67) followed by thiacloprid (6.00). Lufenuron (6.67) was the next best effective treatment against pod fly infestation followed by spinosad which was on par with diafenthiuron and recorded same mean number of maggots or pupae (7.33). Whereas, the highest mean number of maggots or pupae were observed in azadirachtin (10.67) treatment, followed by flubendiamide (9.33). All the insecticide treatments were significantly superior over untreated control (38.67) (Table 1) in reducing pod fly pest load or counts.

Fifteen days after second application during 2020, it was found that all the insecticidal treatments were significantly superior over the control (Table 2). Among the treatments, dinotefuran (4.67) and acetamiprid (5.33) remained superior by recording the lowest number of maggots or pupae per 100 pods and were found on par with each other followed by thiacloprid (5.67). Thiamethoxam + jaggery (7.33) and lufenuron (7.67) were the next best effective treatments and were statistically on par. These treatments were followed by spinosad (8.00) and diafenthiuron (9.33). Flubendiamide (11.00) and azadirachtin (12.67) were found least effective against *M. obtusa* even fifteen days after second spray.

At fifteen days after second spray, it was found that all the nine treatments were found significantly superior over control by recording less number of maggots or pupae of pod fly in treated plots as compared to untreated check (pooled data; Table 3). Dinotefuran (4.33) and acetamiprid (5.00) were emerged as the most effective treatments by recording the least number of maggots or pupae of pod fly per 100 pods compared to other treatments. Thiacloprid

TABLE 3

Efficacy of selected insecticides against pigeonpea pod fly, *M. obtusa* (Pooled data)

Treatment	No. of maggots/pupae 15 DAS (per 100 pods)		% pod damage**	Reduction in pod damage over control (%)	% grain damage**	Per cent reduction in grain damage over control	Grain yield (kg/ha)
	First spray*	Second spray*					
Spinosad 45% SC @ 0.2 ml/l	12.83 (3.62) [bc]	7.67 (2.85) [bcd]	14.00 (21.99) [ab]	61.82	8.65 (17.04) [b]	72.48	2155
Diafenthiuron 50% WP @ 1.0 g/l	15.83 (4.03) [cd]	8.33 (2.94) [cd]	21.50 (27.55) [c]	41.37	12.29 (20.42) [c]	60.90	2010
Dinotefuran 20% SG @ 0.3 g/l	8.67 (3.02) [a]	4.33 (2.19) [a]	10.67 (18.95) [a]	70.90	5.42 (13.33) [a]	82.76	2243
Flubendiamide 39.35% SC @ 0.3 ml/l	16.50 (4.11) [cd]	10.17 (3.25) [de]	21.83 (27.74) [c]	40.47	14.15 (20.02) [c]	54.98	1963
Lufenuron 5.4% EC @ 1.0 ml/l	12.50 (3.60) [bc]	7.17 (2.75) [bc]	16.17 (23.57) [b]	55.90	11.92 (20.78) [c]	62.07	2071
Thiamethoxam 25% WG @ 0.4 g + Jaggery @ 5.0 g/l	9.00 (3.07) [a]	5.83 (2.49) [ab]	12.33 (20.44) [ab]	66.38	7.79 (16.04) [b]	75.21	2172
Acetamiprid 20% SP @ 0.2 g/l	7.83 (2.85) [a]	5.00 (2.30) [a]	11.50 (19.74) [a]	68.64	5.95 (13.97) [a]	81.07	2249
Thiacloprid 21.7% SC @ 0.7 ml/l	10.83 (3.36) [ab]	5.83 (2.51) [ab]	13.50 (21.45) [ab]	63.19	7.61 (15.89) [b]	75.79	2189
Azadirachtin 0.15% EC @ 5.0 ml/l	18.33 (4.30) [d]	11.67 (3.48) [e]	25.67 (30.41) [c]	30.00	17.67 (24.58) [d]	43.78	1840
Control (untreated)	29.83 (5.50) [e]	40.17 (6.37) [f]	36.67 (37.24) [d]	-	31.43 (34.05) [e]	-	1646
S.Em±	0.15	0.14	1.15	-	0.51	-	-
CD at 5%	0.46	0.41	3.42	-	1.50	-	-

**Values in parentheses are Arc sine transformed, * Values in parentheses are SQRT transformed. DAS- Days after spray, Values in each column followed by same alphabet(s) are not significantly different and thiamethoxam + jaggery were found to be the next best treatments which recorded the same mean number of maggots or pupae (5.83) of pod fly and were found statistically on par with each other. The order of efficacy of remaining insecticides were lufenuron, spinosad, diafenthiuron and flubendiamide which recorded 7.17, 7.67, 8.33 and 10.17 mean number of maggots or pupae per 100 pods, respectively whereas azadirachtin (11.67) was found to be the least effective insecticide in reducing the pod fly population.

Effect of Insecticides on Per Cent Pod Damage

Mean per cent pod damage due to pod fly after treatment revealed that all the treatments were significantly effective in reducing the pod damage at varying intensity and were found superior over untreated control. Dinotefuran (9.67) and acetamiprid (10.67) emerged as the best treatments in reducing per cent pod infestation by pod fly and were on par with each other. These were followed by thiamethoxam + jaggery (12.67) which was on par with thiacloprid (14.67). Spinosad (16.67) and lufenuron (17.00) were the next order effective treatments against pod fly and were on par with each other in reducing the mean per cent pod damage by pod fly followed by diafenthiuron (21.67) and flubendiamide (22.00) and were found on par with each other. Though azadirachtin (25.33) was least effective in reducing pod fly infestation, it was found significantly superior over the control treatment (35.67) (Table 1) during 2019.

All the treatments were effective in curtailing the pod damage by pod fly which varied among themselves and found to be significantly superior over untreated control (Table 2) during 2020. Spinosad (11.33), dinotefuran (11.67), thiamethoxam + jaggery (12.00), acetamiprid (12.33), thiacloprid (12.33) were found on par in reducing infestation by pod fly, followed by lufenuron (15.33). The next best insecticides for reducing pod damage were diafenthiuron (21.33) and flubendiamide (21.67), which were on par with each other. Azadirachtin (26.00) was the least effective among the insecticides against *M. obtusa* pod damage however it was superior over untreated control (37.67).

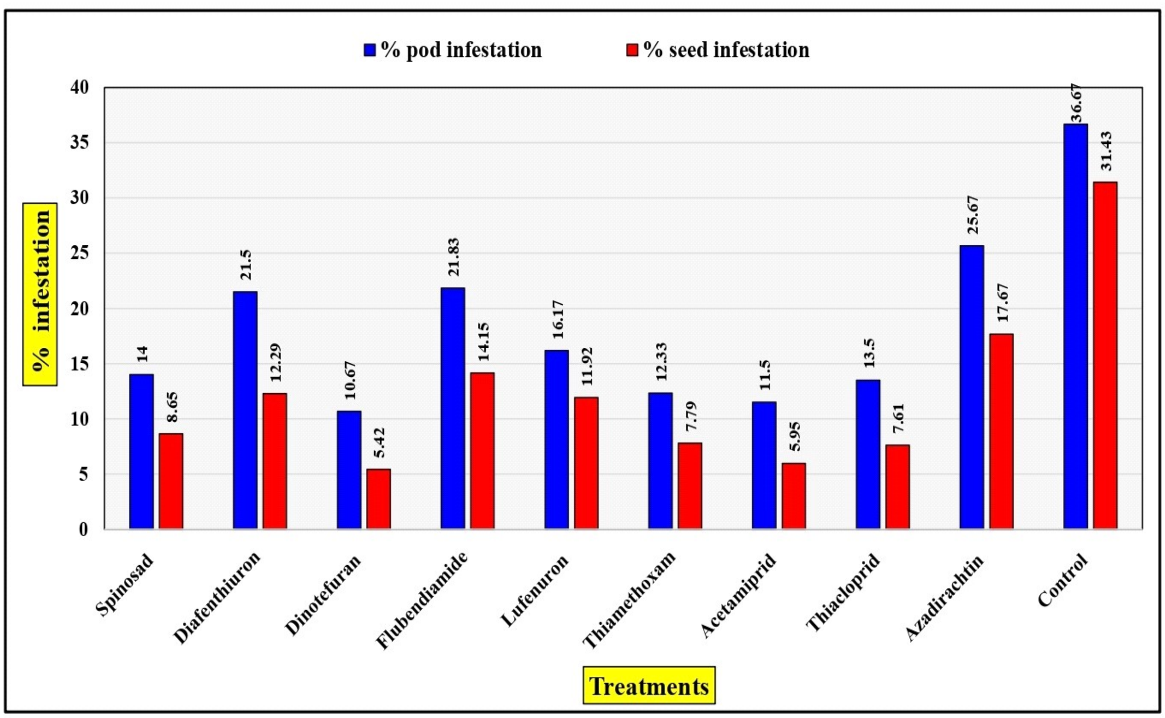

Fig. 1: Efficacy of different insecticides against pod fly, *M. obtusa* in pigeonpea

Out of nine insecticides evaluated against pod fly, dinotefuran (10.67) and acetamiprid (11.50) were recorded as more effective insecticides in reducing pod damage by pod fly and on par with each other (pooled data; Table 3 & Fig. 1). Thiamethoxam + jaggery (12.33) and thiacloprid (13.50) were found to be the next best effective treatments, on par with spinosad (14.00) and followed by lufenuron (16.17). Less effective insecticides in reducing the pod damage due to pod fly were diafenthiuron (21.50) and flubendiamide (21.83) which were on par with azadirachtin (25.67) but were found superior over the control (36.67).

Effect of Insecticides on Per Cent Grain Damage

Results on per cent grain damage revealed that all the insecticidal treatments were significantly superior over control (Table 1). The lowest grain damage was noticed in dinotefuran treatment (4.17) followed by acetamiprid (5.09) and thiamethoxam + jaggery (5.92) and were found on par with thiacloprid (6.15). Spinosad (7.92) emerged as the next best effective treatment against pod fly infestation followed by lufenuron (10.58). Diafenthiuron (11.52), flubendiamide (11.81) and azadirachtin (12.60) were found least effective in reducing per cent grain damage due to pod fly and were statistically on par with each other during 2019.

In comparison to the untreated control (34.55%), all insecticidal treatments exhibited considerably reduced per cent grain damage. Out of nine insecticides tested against pod fly, dinotefuran (6.67%) and acetamiprid (6.80) found as the most effective treatments in reducing per cent grain damage due to pod fly infestation and were found on par with each other. The order of efficacy of next best treatments were thiacloprid (9.06) and spinosad (9.37), which were on par with thiamethoxam + jaggery (9.66) followed by diafenthiuron (13.06). Lufenuron (13.26) and flubendiamide (16.50) were the next best treatments which were on par with each other whereas, azadirachtin (22.74) was the least effective insecticide in reducing per cent seed damage due to pod fly infestation but was significantly superior over the control (Table 2).

When compared to the untreated control, all the insecticide treatments recorded considerable reduction in grain damage (pooled data; Table 3 & Fig. 1). The better insecticidal treatments in reducing grain damage were dinotefuran (5.42) and acetamiprid (5.95) and were on par with each other. Followed by, thiacloprid (7.61) and thiamethoxam + jaggery (7.79), which, were statistically on par with spinosad (8.65) in reducing grain damage due to pod fly. Lufenuron (11.92), diafenthiuron (12.29) and flubendiamide (14.15) were the next better treatments and were statistically on par. Azadirachtin (17.67) application was observed to be the least effective treatment against pod fly infestation insecticides treatments.

In the present study among the nine different insecticides tested dinotefuran 20% SG @ 0.3g/l and acetamiprid 20% SP @ 0.2 g/l were superior and recorded the lowest pod damage and grain damage by *M. obtusa*. These findings are in concurrence with that of Nithish and Rana (2019) who also recorded the minimal pod damage (5.43%) and grain damage (3.26%) by *M. obtusa* with the application of acetamiprid 20% SP @ 20 g a.i./ha. Similar findings were reported by Premkumari (2018) who found that acetamiprid showed maximum effectiveness with 61.44 per cent reduction in maggot population in comparison to control. Current findings were also supported by Sharma *et al.* (2011) who reported that combination of emamectin benzoate 5 per cent SG (11g a.i./ha) with acetamiprid 20% SP (0.008%) treatment recorded the higher grain yield of 1399 kg/ha and lower grain damage (13.30) as compared to other bio-pesticides tested against pod fly.

The next statistically superior treatments observed in current chemical evaluation were thiacloprid 21.7% SC @ 0.7ml/l and thiamethoxam 25% WG @ 0.4 g/l + jaggery @ 5.0 g/l. These results were comparable with Srujana and Keval (2013) who observed that thiamethoxam 25% WG @ 75 g a.i./ha treated plots recorded the least per cent pod damage (17.33) and grain damage (6.77) and they also observed that three sprays of insecticides starting with 50 per cent flowing at fifteen days interval worked well against *M. obtusa.* The present findings were in close agreement with the Patra *et al.* (2017) who reported that thiamethoxam and spinosad performed best against pod fly by recording the least pod damage of 19.55 per cent and 22.69 per cent, respectively. These findings were in partial agreement with Kumar *et al*. (2016) who found numerically lowest pod damage of 4.33 per cent in methomyl 40% SP @ 0.6 g/l followed by thiamethoxam 25% WG @ 0.25 g/l. Similarly, Gogi (2003) reported that *M. obtusa* infestation was lowest in plots treated with thiacloprid 21.7% SC (750 a.i./ ha) and recorded lower pod damage (2.71%). However, these findings were contradictory to Vikram *et al.* (2015) who reported that thiacloprid 21.7% SC was the least effective chemical against pod fly and recorded the maximum pod damage of 28.00 per cent.

Spinosad and lufenuron were observed to be moderately effective in reducing pod fly infestation. These observations were in partial agreement with Ghetiya (2010) who found that the mean grain damage at harvest had significantly lower when crop was treated with indoxacarb (0.007%), which remained at par with spinosad (0.009%) and endosulfan (0.07%) in which grain damage was observed 0.91 and 1.43 per cent, respectively.

Sreekanth *et al*. (2014) also found that the pod damage from two seasons trials was significantly low in plots treated with spinosad 45% SC at 0.3 ml/l (10.2%). Indrasen *et al*. (2017) also found that lufenuron 5.4% EC (30 g a.i./ha) was the less effective chemical against pod fly and treated plots recorded the pod damage of 24.33 per cent. Dastgir (2007) found that lowest grain damage and highest grain yield was recorded in plots treated with spinosad @ 90 g a.i./ha (21.32% and 1681 kg/ha, respectively).

In the present chemical evaluation studies, diafenthiuron, flubendiamide and azadirachtin were found less effective against pod fly. These findings were supported by Singh (2014) who also observed same trend with flubendiamide (47 g a.i./ha) which showed moderate effectiveness against pod fly and recorded per cent pod damage of 14.00 and grain damage of 11.33. However, these findings were slight contradictory to Sreekanth *et al*. (2020) who observed that among different insecticides, thiacloprid 21.7 % SC @ 0.7 ml/l, followed by diafenthiuron 50% WP @ 1.5 g/l, flubendiamide 39.35% SC 0.2 ml/l and dimethoate 30% EC @ 2ml/l were found to be very effective against pod fly with maximum reduction in per cent pod damage of 75.40, 71.50, 70.50 and 68.00, respectively over the control.

Ghetiya (2010) found that azadirachtin was the least effective chemical against *M. obtusa* who observed higher (28.73%) grain damage in unsprayed crop, which was at par with Btk (1.25 l/ha) and NSKE (5%) in which grain damage was observed 27.77 per cent and 12.99 per cent, respectively. Patel and Patel (2013) also found that treatments *viz.,* lambda cyhalothrin 4.9% CS @ 25 g a.i./ha, NSKE @ 5%, *Bacillus thuringiensis* @ 750 g/ha and neem oil @ 0.5% registered 11.13, 12.31, 12.83, 13.16 and 13.49 per cent pod damage due to *M. obtusa*, respectively and concluded, that these treatments were less effective against *M. obtusa*. The present findings were also in conformity with pooled data of two years study done by Kumar *et al*. (2016) who observed that botanicals like neem seed kernel extract (NSKE @ 5%) and garlic + chilli + kerosene extract (GCKE @ 1%) were least effective against pod fly and were found on par with each other and recorded maximum per cent pod damage and grain damage of 23.29, 27.06 and 12.56, 13.43, respectively.

Incremental Cost Benefit Ratio (Pooled)

The data showed that all insecticides resulted in significantly higher yields (Table 4) than the untreated control. Among the nine treatments, acetamiprid recorded the highest yield (2249 kg/ha) and the lowest yield was recorded in plots treated with azadirachtin (1840 kg/ha). The ICBR ratio varied from 1:0.28 to 1:12.92. The highest ICBR ratio was recorded with acetamiprid (1:12.92) followed by thiamethoxam (1:6.17), dinotefuran (1:4.27). These findings were in concurrence with Sreekanth *et al.* (2020) who observed that the highest ICBR was obtained with dimethoate 30% EC @ 2.0 ml/l (1:6.00), followed by thiacloprid 21.7% SC @ 0.7 ml/l (1:5.14), profenophos 50% EC @ 2.0 ml/l (1:4.64), acetamiprid 20% SP @ 0.2 g/l (1: 4.49). Additionally, according to Sreekanth *et al.* (2013), grain damage owing to pod

TABLE 4

Economics and efficacy of selected insecticides against pigeonpea pod fly infestation (Pooled data)

Treatment	Grain yield (kg/ha)	Increase in yield over control (%)	Returns of increased yield over control (Rs./ha) (A)	Plant protection cost/ha (Rs./ha) (B)	Net returns over control (Rs./ha) (A-B)	Incremental Cost Benefit Ratio (ICBR) (A-B)/B
Spinosad 45% SC @ 0.2 ml/l	2155	30.92	30540	8933	21607	2.42
Diafenthiuron 50% WP @ 1.0 g/l	2010	22.11	21840	12400	9440	0.76
Dinotefuran 20% SG @ 0.3 g/l	2243	36.27	35820	6800	29020	4.27
Flubendiamide 39. 35% SC @ 0.3 ml/l	1963	19.26	19020	14900	4120	0.28
Lufenuron 5.4% EC @ 1 ml/l	2071	25.82	25500	9200	16300	1.77
Thiamethoxam 25% WG @ 0.4 g + Jaggery @ 5.0 g/l	2172	31.96	31560	4400	27160	6.17
Acetamiprid 20% SP @ 0.2 g/l	2249	36.63	36180	2600	33580	12.92
Thiacloprid 21.7% SC @ 0.7 ml/l	2189	32.99	32580	6900	25680	3.72
Azadirachtin 0.15% EC @ 5 ml/l	1840	11.79	11640	7500	4140	0.55
Control (untreated)	1646	-	-	-	-	-

Pigeonpea price @ Rs. 6000/quintal. Spinosad 45% SC @ Rs. 1700/75 ml, diafenthiuron 50% WP @ Rs. 5200/kg, dinotefuran 20% SG @ Rs. 400/50 g, flubendiamide 39.35% SC @ Rs. 215/10 ml, lufenuron 5.4% EC @ Rs. 900/250 ml, thiamethoxam 25% WG @ Rs. 300/100 g, acetamiprid 20% SP @ Rs. 150/l00 g, thiacloprid 21.7% SC @ Rs. 350/100 ml, azadirachtin 0.15% @ Rs. 550/l fly was low in dimethoate (14.0%) followed by acetamiprid (22.6%) treatments with ICBR of 1: 6.16 and 1: 4.11, respectively. The results revealed that two sprays of acetamiprid 20% SP @ 0.2 g/l at fifteen days interval starting from 50 per cent flowering stage work well against pod fly and may be recommended to the farmers for effective control of pod fly. Moreover, acetamiprid treatment also resulted in highest Incremental Cost Benefit Ratio (ICBR) of 1:12.92. Further, though dinotefuran 20% SG @ 0.3 g/l was equally effective as that of acetamiprid 20% SP @ 0.2 g/l, it resulted relatively lower ICBR (1:4.27) compared to thiamethoxam 25% WG @ 0.4 g/l + jaggery 5 g/l (1: 6.17). So, from farmers point of view, it can be concluded that thiamethoxam 25% WG @ 0.4 g/l + jaggery @ 5 g/l with ICBR of 1: 6.17 can be considered as the second best treatment which can be recommended to the pigeonpea farmers.

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