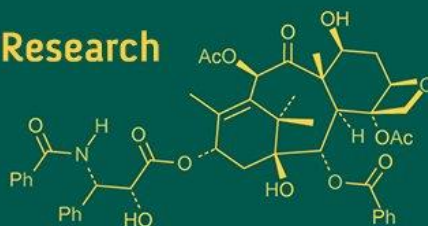


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Impact of various insecticide modules on stem fly and girdle beetle of soybean

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Abstract

The present investigation was conducted during *Kharif* 2025 at the Research Field of the Department of Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra, to evaluate the efficacy, safety to natural enemies, yield potential and economics of different insecticide modules against stem fly and girdle beetle of soybean. The experiment was conducted in a Randomized Block Design with five treatments and four replications using soybean variety JS- 335. The results revealed that all the insecticide modules were significantly effective over the untreated control in reducing stem fly and girdle beetle infestation. Module M1 comprising imidacloprid 48% FS seed treatment followed by foliar spray of isocycloseram 9.2% DC and thiamethoxam 12.60% + lambda-cyhalothrin 9.50% ZC recorded the lowest cumulative stem fly infestation (4.70%), closely followed by M2 (4.71%). Against girdle beetle, M2 comprising thiamethoxam 30% FS seed treatment followed by foliar spray tetraniliprole 18.18 SC and chlorantraniliprole 9.30% + lambda-cyhalothrin 4.60% ZC recorded the lowest cumulative infestation (4.64%). The populations of ladybird beetles and spiders did not differ significantly among the insecticide modules, indicating their comparatively safer nature towards these natural enemies. Module M2 recorded the highest soybean yield of 15.92 q/ha, followed by M1 with 13.19 q/ha, compared with 6.71 q/ha in the untreated control. Economically, M2 proved to be the most profitable module, recording the highest incremental cost-benefit ratio (ICBR) of 1:6.89 and a net profit of ₹42854 per ha. Thus, the module consisting of thiamethoxam 30% FS followed by tetraniliprole 18.18 SC and chlorantraniliprole 9.30% + lambda-cyhalothrin 4.60% ZC was found to be the most effective and economically viable insecticidal module for the management of stem fly and girdle beetle of soybean.

Keywords: Soybean, *Melanagromyza sojae*, *Obereopsis brevis*, insecticide modules, natural enemies, ICBR

Introduction

Soybean (*Glycine max.*) is one of the most important leguminous crop. It has a broad range of geographical adaptations, very high nutritional value, unique chemical composition, functional health benefits and versatile end uses due to which it is an important agricultural commodity. Soybean provides 55 percent of the worldwide vegetable oil production and contribute about 50 percent of the world's protein concentrate for poultry, livestock, and fish feeding (Pratap *et al.*, 2016) [15].

The area, production and productivity of soybean in India during 2024 - 2025 was about 28.94 million hectare, 37.96 million tonnes and 1312 kg/ha, respectively. Whereas the area, production and productivity of soybean in Maharashtra during 2024-2025 was about 5.21 million hectares, 4.70 million tonnes and 901 kg/ha, respectively. (Indiastat agri. com) [5]. Biotic and abiotic challenges such as weeds, drought, diseases and insect pests are attributed to low soybean production at the national and state levels. Insect pests are one of the most serious threats to soybean production, since they increase the cost of cultivation and decrease the quality of the crop in a kind of ways.

Stem fly, *Melanagromyza sojae* Zehntner (Diptera: Agromyzidae) has emerged as a major pest in the soybean growing areas of India over the last two decades (Gaur *et al.* 2015) [4]. The soybean crop is prone to heavy infestation by *Melanagromyza sojae* at all the stages of growth and development, right from seedling to maturity. The maggot of stem fly enters the stem through the leaf petiole, feeds on the stem pith by mining both upwards and downwards

and makes a reddish coloured tunnel in the affected plant (Van den Berg et.al. 2000). Infestations in the early growth stages or crop causes high seedling mortality and reduce the crop stand. Infestations during later growth stages do not kill the damaged plants, however they may significantly affect the yield attributing characters of the plant. (Singh and Beri 1971; Talekar, 1990; Van den Berg et. al.2000; Savaji, 2006). Stem fly causes 16-20% damage in soybean crop during *Kharif* season (Anonymous, 2007) ^[1, 18, 20].

The Girdle beetle *Obereopsis brevis* (Swedenboard) which belongs to family Cerambycidae is a serious growing menace to soybean crop. The initial damage caused by the female, which makes two parallel girdles with its mandibles either on petiole, branch or main stem for egg laying. These girdles reduce the water supply in plants which turn ensures successful hatching of eggs. It has been observed that girdle beetle cause higher reduction in yield and identified in between 30 to 55 days when girdler confined to petiole. (Chaudhary et.al.2014) ^[2]. Girdle beetle happens a serious

pest of soybean and reduce about 14 to 42 percent yield. (Patel et al., 2019) ^[13].

Out of various methods of pest management, use of chemical insecticides is most preferred by the farmers as it gives quick visible effects and easily available. In recent years number of chemical insecticides along with ready mix combination and novel mode of action are available in the market. In such conditions it becomes necessary to evaluate the efficacy of these products against the targeted pests and critically inspect for their adverse effects on the natural enemies.

Materials and Methods

The present investigation was conducted during the *Kharif* 2025 at the Research Field of Department of Entomology, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra to evaluate the efficacy of various insecticide modules against stem fly and girdle beetle of soybean.

Table 1: Experimental Details

Parameter	Details
Design of experiment	Randomized Block Design (RBD)
Treatments	Five
Replications	Four
Season	<i>Kharif</i> 2025
Crop	Soybean
Variety	JS - 335
Spacing	45 cm x 5 cm
Plot Size	Gross: 5 m x 5 m Net: 4.1 m x 4.9 m
Fertilizer Dose	30: 70: 30 NPK Kg/ha
Date of sowing	25th June, 2025

Table 2: Treatment Details

Module No.	Insecticide Details
M1	Imidacloprid 48% FS @ 1.25 ml/kg seed Fb Isocycloseram 9.2% w/w DC @ 12 ml / 10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml / 10 lit
M2	Thiamethoxam 30% FS 10 ml /kg seed Fb Tetranilliprole 18.18 SC @ 5 ml /10 lit Fb Chlorantranilliprole 9.30 % + Lambda Cyhalothrin 4.60% ZC @ 4 ml / 10 lit
M3	Thiamethoxam 25% WG @ 6 g /kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml /10 lit
M4	Flonicamid 50% WG @ 4 g/10 lit Fb Emamectin benzoate 1.90% EC @ 8.5 ml /10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g/10 lit
M5	Untreated Control

Method of recording observations

Stem fly: The observations on stem fly were recorded from five randomly selected spots of one metre row length in each net plot at weekly interval. The number of plants damaged due to stem fly were observed and percent infestation was worked out.

Girdle beetle

The observations on girdle beetle were recorded from five randomly selected spots of one metre row length in each net plot at weekly interval. The number of plants damaged due to girdle beetle were observed and percent infestation was calculated.

Natural enemies

The observations on natural enemies were recorded from five selected spots of one metre row length in each net plot at weekly interval.

Result and Discussion

Efficacy of different insecticide modules against Soybean Stem fly At 27th meteorological week (2 - 8 july 2025)

The data presented in Table 3 pertaining to percent infestation of soybean stem fly at 27th meteorological week revealed that all the insecticide modules were found effective over untreated control. The minimum stem fly infestation of 2.50% recorded in M1 (Imidacloprid 48% FS @ 1.25 ml /kg seed Fb Isocycloseram 9.2%w/w DC @ 12 ml / 10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml / 10 lit) This treatment was found at par with module M2 (Thiamethoxam 30% FS 10 ml /kg seed Fb Tetranilliprole 18.18 SC @ 5 ml /10 lit Fb Chlorantranilliprole 9.30% + Lambda Cyhalothrin 4.60% ZC @ 4 ml / 10 lit) and M3 (Thiamethoxam 25% WG @ 6 g /kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml /10 lit) which recorded 2.80% and 3.40%, stem fly infestation respectively. Whereas M4 (Flonicamid 50% WG

@ 4 g/10 lit Fb Eamectin benzoate 1.90% EC @ 8.5 ml /10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g /10 lit), the module which was without seed treatment recorded 4.20% stem fly infestation and found at par with untreated control (4.80%).

At 28th meteorological week (9 - 15 July 2025)

It is evident from the data presented in Table 3 that all the insecticide modules were effective over untreated control in recording least percent infestation of stem fly on at 28th meteorological week. Among the different modules, module 1 recorded minimum percent infestation of stem fly (2.80%) which was at par with M2 and M3 with 3.20% and 3.80%, respectively. The Module M4 and module M5 recorded maximum infestation of stem fly (i.e. 4.80% and 5.20%), respectively.

At 30th meteorological week (23 - 29 July 2025)

The data depicted in Table 3 showed that all the insecticide modules were significantly effective over untreated control in recording less percent infestation of stem fly at 30th meteorological week. Among the different insecticide modules, module 1 recorded minimum percent infestation of stem fly (3.88%) and found at par with M2 (4.38%), M3 (5.00%), and M4 (5.31%). The untreated control recorded maximum stem fly infestation (8.75%).

At 31st meteorological week (30 - 5 Aug 2025)

The data indicated in Table 3 showed that all the insecticide modules were significantly effective over untreated control in recording least percent infestation of stem fly at 31st meteorological week. Among the different insecticide modules, Module 1 recorded minimum percent infestation of stem fly of 4.38% which was at par with module M2 and M3 with 5.25% and 5.63%, respectively. The module M4 found moderately effective in this respect (6.25%). The untreated control recorded highest percent stem fly infestation of 10.25%.

At 32nd meteorological week (6 - 12 Aug 2025)

The data presented in Table 3 pertaining to efficacy of different insecticide modules against stem fly revealed that all the treatment found effective over untreated control. The module 1 was found most effective and recorded minimum percent infestation of stem fly (5.63%). The module 1 was also found at par with M2 recorded 6.25% and M3 (6.88%) stem fly infestation. The module M4 recorded 7.50% percent stem fly infestation and found at par with M5 (8.75%).

At 33rd meteorological week (13 - 19 Aug 2025)

The data depicted in Table 3 showed that all the insecticide modules were significantly effective over untreated control in recording least percent infestation of stem fly at 33rd meteorological week. Among the different insecticide modules, Module 4 recorded minimum percent infestation of Stem fly (4.00%). This module was found at par with M2, M3 and M1 with 4.80%, 4.50% and 5.20% stem fly infestation, respectively. Whereas highest stem fly infestation was recorded in untreated control (9.00%).

At 34th meteorological week (20 - 26 July 2025)

The data on stem fly infestation recorded at 34th meteorological week, Table 3 revealed that module M4

recorded minimum stem fly infestation (5.13%). The M4 was also found at par with M3, M2, M1 which recorded 5.63%, 6.25%, and 6.88% percent stem fly infestation, respectively. The untreated control recorded highest stem fly infestation (9.38%).

At 35th meteorological week (27 - 2 September 2025)

The data presented in Table 3 shows the percent stem fly infestation recorded at 35th meteorological week. The data revealed that all the insecticide modules were found significantly effective over untreated control. Among the different insecticide modules, module 2 recorded minimum percent infestation of stem fly i.e. 4.38%. It was followed by M1 (4.69%), M3 (5.00%) and M4 (5.75%). However all these treatments found at par with each other. The highest percent stem fly infestation was recorded in untreated control (8.75%).

At 36th meteorological week (3 - 9 September 2025)

The data pertaining to stem fly infestation recorded at 36th meteorological week, Table 3 revealed that, the module M2 recorded minimum percent infestation of stem fly (4.40%). However this treatment module was found at par with module M1, M3, and M4 which recorded 5.00%, 5.31%, and 5.94% percent stem fly infestation, respectively. The untreated control recorded maximum stem fly infestation (8.13%).

At 37th meteorological week (10 - 16 September 2025)

The data depicted in Table 3 showed that all the insecticide modules were significantly effective over untreated control in recording least percent infestation of stem fly at 37th meteorological week. Among the different insecticide module, Module 2 recorded minimum percent infestation of Stem fly (5.40%). It was followed by M1 (6.00%), M3 (6.50%) and M4 (7.20%), respectively. However all treatment module found statistically equal with each other. The untreated control recorded highest stem fly infestation i.e. 10.50%.

Cumulative effect of different insecticide modules against Soybean stem fly

The cumulative data presented in Table 3 pertaining to stem fly infestation revealed that all the modules proved significantly effective over untreated control. Among the different treatments, module 1 (4.70%) recorded minimum percent infestation of stem fly and found at par with module M2, M3 and M4 which recorded 4.71%, 5.17% and 5.61%, respectively. However the untreated control recorded highest percent infestation of 8.35%.

The present findings pertaining to stem fly (*Melanagromyza sojae*) percent infestation are in agreement with the finding of earlier workers like Shete et. al. (2018) ^[16] who reported that the seed treatment with Imidacloprid 48% FS @ 1.25 ml/kg seed proved to be the most effective against the major insect pests of soybean, including stem fly up to 30 DAG, and found at par with thiamethoxam 30% FS. Lokhande et. al. (2024) ^[9] revealed that treatment module (Indoxacarb 15.80% EC followed by Chlorantraniliprole 9.30% + Lambda-cyhalothrin 4.60% ZC + Propiconazole 25% EC) recorded the lowest stem fly infestation (1.51%), It was followed by treatment module [Chlorantraniliprole 18.50% SC followed by Thiamethoxam 12.60% + Lambda-cyhalothrin 9.50% ZC + Propiconazole 25% EC]. Longchar

et. al. (2019) ^[10], reported that Thiamethoxam 30 FS @ 10 ml kg⁻¹ seed was the most effective treatment, as it maintained zero stem fly infestation throughout the experimental period. Chand et.al. (2015) the experiment was carried out by using different new insecticides viz., Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC (Alika 247 ZC) @ 22 g ai/ha, Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC (Alika 247 ZC) @ 27.5 g ai/ha, Thiamethoxam 12.6% + Lambda-cyhalothrin 9.5% ZC (Alika 247 ZC) @ 33 g ai/ha, Thiamethoxam 25% WG, Lambda cyhalothrin 4.9% CS, Ethion 50% EC, Imidacloprid 17.8% SL against stem fly infestation. Result showed that percent tunnelling was least in Alika 247 ZC @ 33 g ai/ha about 30.55% as compared to 42.32% in untreated plot. Upadhyay et. al. (2017) ^[19] studied the effect of insecticides on incidence of stem fly the lowest plant infestation was recorded in Imidacloprid @ 5ml/kg seed (ST) whereas least stem tunneling was recorded in Imidacloprid @ 5ml/kg seed (ST) followed by Triazophos 40 EC @ 800ml/ha after 20 days.

Efficacy of different insecticide modules against girdle beetle at 30th meteorological week (23 - 29 July 2025)

The data depicted in Table 4 showing the percent infestation of girdle beetle recorded at 30th M. W. Among the different modules M 1 (Imidacloprid 48% FS @ 1.25 ml /kg seed Fb Isocycloseram 9.2% w/w DC @ 12 ml / 10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml / 10 lit) recorded minimum percent infestation of girdle beetle (3.75%). This treatment was found at par with module M2 (Thiamethoxam 30% FS fb 10 ml /kg seed Fb Tetranilliprole 18.18 SC @ 5 ml /10 lit Fb Chlorantranilliprole 9.30% + Lambda Cyhalothrin 4.60 ZC @ 4 ml / 10 lit) with 4.38 percent and M3 (Thiamethoxam 25% WG @ 6 g /kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml /10 lit) with 5.00% percent girdle beetle infestation. Whereas the module M4 (Flonicamid 50% WG @ 4 g/10 lit Fb Emaxectin benzoate 1.90% EC @ 8.5 ml /10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g /10 lit) (5.94%) was found at par with M5 (untreated control). The maximum percent infestation of girdle beetle was recorded in untreated control i.e. 6.25 percent.

At 31st meteorological week (30 - 5 August 2025)

The data on girdle beetle infestation recorded at 31st M. W. is depicted in Table 4 Among the treatments, the module M1 found most effective with 4.69% percent infestation of girdle beetle which was at par with M2 (5.00%) and M3 (5.31%). Whereas comparatively more infestation of girdle beetle was recorded in module 4 (6.88%). However this module was found at par with untreated control (7.19%).

At 32nd meteorological week (6 - 12 August 2025)

The data presented in Table 4 pertaining to percent infestation of girdle beetle recorded at 32nd meteorological week revealed that all the insecticide modules were found significantly effective over control. The minimum girdle beetle infestation of 4.80% was recorded in M1. This treatment was found at par with M2, M3 and M4 which recorded 5.40%, 5.80% and 6.40% girdle beetle infestation, respectively. Whereas the module M5 recorded maximum percent infestation of girdle beetle i.e. 10.00%.

At 33rd meteorological week (13- 19 August 2025)

The data on girdle beetle infestation recorded at 33rd meteorological week Table 4 revealed that module M4 recorded minimum girdle beetle infestation (3.75%). The M4 was also found at par with M3, M2 and M1 which recorded 4.06%, 4.38% and 4.44% stem fly infestation, respectively. Whereas the untreated control recorded 8.75% percent girdle beetle infestation.

At 34th meteorological week (20 - 26 August 2025)

The data in Table 4 showed that all the insecticide modules were significantly effective over untreated control in recording lesser percent infestation of girdle beetle at 34th meteorological week. Among the different insecticide modules, Module M4 recorded minimum percent infestation of girdle beetle (4.00%). This module was found at par with M3 M2 and M1 with 4.50%, 4.80% and 5.20% respectively. However highest girdle beetle infestation recorded in untreated control (9.00%).

At 35th meteorological week (27 - 2 September 2025)

The data pertaining to girdle beetle infestation recorded at 35th meteorological week, Table 4 revealed that module M2 recorded minimum percent infestation of girdle beetle (3.13%). However, this treatment module was found at par with module M1, M3 and M4 which recorded 3.25%, 3.44% and 3.75% percent girdle beetle infestation, respectively. The untreated control recorded maximum girdle beetle infestation (7.50%).

At 36th meteorological week (3- 9 September 2025)

The data presented in Table 4 shows percent girdle beetle infestation recorded at 36th meteorological week. The data revealed that all the treatment modules were found significantly effective over untreated control. Among the different insecticide module M2 recorded minimum percent infestation of girdle beetle i.e. 4.80%. This was followed by M1, M3 and M4 recorded 5.40%, 5.80% and 6.40% percent girdle beetle infestation, respectively. However all these treatments were found statistically at par with each other. The highest percent girdle beetle infestation was recorded in untreated control i.e. (10.00%).

At 37th meteorological week (10 - 16 September 2025)

The data indicated in Table 4 showed that all the insecticide modules were significantly effective over untreated control in recording least percent infestation of girdle beetle at 37th meteorological week. Among the different insecticide modules M2 recorded minimum percent infestation of girdle beetle (5.20%) which was at par with module M1, M3 and M4 with 6.00%, 6.40% and 6.80%, respectively. The untreated control recorded highest percent girdle beetle infestation (10.50%).

Cumulative effect of different insecticide modules against girdle beetle

The cumulative data presented in Table 2 revealed that all the insecticide modules found statistically superior over untreated control. Among the different modules, module M2 recorded minimum percent infestation of girdle beetle (4.64%). However the module M2 was found statistically at par with module M1 (4.69%), M3 (5.04%) and M4 (5.49%). The untreated control recorded maximum percent infestation of girdle beetle i.e. (8.65%).

The present findings pertaining to girdle beetle (*Obereopsis brevis*) percent infestation are in agreement with the finding of earlier workers like Shete et al. (2018) [16] who evaluated different seed treatment for the management of soybean pests. The results indicated that the seed treatment with imidacloprid 48% FS @ 1.25 ml/kg seed proved to be most effective against major pests of soybean, including girdle beetle up to 30 day after germination and found at par with thiamethoxam 30% FS. Dhore et al. (2024) [3] reported that treatments of chlorantraniliprole 10% + lambda-cyhalothrin 5% ZC @ 150 ml ha⁻¹ proved to be the most effective, recording the lowest girdle beetle infestation (1.47%) per

cent. Patel et al. (2019) [13] evaluated the efficacy of new insecticide molecules against soybean girdle beetle reported 1.25 1.33 and 1.88 girdle beetle rings / mrl in plots treated with Thiamethoxam 12.6% Lambda cyhalothrin 9.5% ZC, Indoxacarb 15.80 EC and Betacyfluthrin 8.49%+ Imidacloprid 19.81% 300 OD, respectively. Kambreakar (2020) [8] reported the highest efficacy of Chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC @ 200 ml ha⁻¹ proved to be the most effective against the major lepidopteran insect pests of soybean.

Table 3: Effect of different insecticide modules against Stem fly

Mod	Treatment Details	7 July	15 July	23 July	31 July	7 Aug	16 Aug	24 Aug	1 Sept	8 Sept	16 Sept	Cumulative Average
M ₁	Imidacloprid 48% FS @ 1.25 ml/kg seed Fb Isocycloseram 9.2% w/w DC @ 12 ml/10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml/10 lit	2.50 (1.50)	2.80 (1.67)	3.88 (1.96)	4.38 (2.08)	5.63 (2.36)	5.20 (2.26)	6.88 (2.61)	4.69 (2.15)	5.00 (2.23)	6.00 (2.44)	4.70 (2.13)
M ₂	Thiamethoxam 30% FS @ 10 ml/kg seed Fb Tetraniliprole 18.18 SC @ 5 ml/10 lit Fb Chlorantraniliprole 9.30% + Lambda Cyhalothrin 4.60% ZC @ 4 ml/10 lit	2.80 (1.67)	3.20 (1.78)	4.38 (2.08)	5.25 (2.28)	6.25 (2.49)	4.80 (2.18)	6.25 (2.48)	4.38 (2.08)	4.40 (2.10)	5.40 (2.32)	4.71 (2.15)
M ₃	Thiamethoxam 25% WG @ 6 g/kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml/10 lit	3.40 (1.84)	3.80 (1.94)	5.00 (2.22)	5.63 (2.36)	6.88 (2.61)	4.50 (2.11)	5.63 (2.36)	5.00 (2.23)	5.31 (2.29)	6.50 (2.54)	5.17 (2.25)
M ₄	Flonicamid 50% WG @ 4 g/10 lit Fb Emamectin benzoate 1.90% EC @ 8.5 ml/10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g/10 lit	4.20 (2.04)	4.80 (2.18)	5.31 (2.29)	6.25 (2.49)	7.50 (2.73)	4.00 (1.99)	5.13 (2.25)	5.75 (2.38)	5.94 (2.42)	7.20 (2.67)	5.61 (2.34)
M ₅	Untreated Control	4.80 (2.18)	5.20 (2.27)	8.75 (2.95)	10.25 (3.18)	8.75 (2.95)	9.00 (2.99)	9.38 (3.05)	8.75 (2.95)	8.13 (2.84)	10.50 (3.23)	8.35 (2.86)
	F Test	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG
	SE (m) ±	0.15	0.11	0.14	0.13	0.12	0.14	0.15	0.13	0.15	0.13	0.14
	CD at 5%	0.47	0.34	0.42	0.41	0.37	0.42	0.45	0.41	0.46	0.35	0.41
	CV%	16.52	11.11	11.97	10.70	9.05	11.81	11.43	11.38	12.49	9.63	11.61

Note: Figures in parentheses are corresponding square root transformation values.

Table 4: Effect of different insecticide modules against Girdle beetle

Mod	Treatment Details	23 July	31 July	7 Aug	16 Aug	24 Aug	1 Sept	8 Sept	16 Sept	Cumulative Average
M ₁	Imidacloprid 48% FS @ 1.25 ml/kg seed Fb Isocycloseram 9.2% w/w DC @ 12 ml/10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml/10 lit	3.75 (1.93)	4.69 (2.15)	4.80 (2.18)	4.44 (2.09)	5.20 (2.26)	3.25 (1.79)	5.40 (2.31)	6.00 (2.44)	4.69 (2.17)
M ₂	Thiamethoxam 30% FS @ 10 ml/kg seed Fb Tetraniliprole 18.18 SC @ 5 ml/10 lit Fb Chlorantraniliprole 9.30% + Lambda Cyhalothrin 4.60% ZC @ 4 ml/10 lit	4.38 (2.08)	5.00 (2.23)	5.40 (2.31)	4.38 (2.09)	4.80 (2.18)	3.13 (1.76)	4.80 (2.18)	5.20 (2.27)	4.64 (2.14)
M ₃	Thiamethoxam 25% WG @ 6 g/kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml/10 lit	5.00 (2.23)	5.31 (2.29)	5.80 (2.39)	4.06 (2.01)	4.50 (2.11)	3.44 (1.85)	5.80 (2.39)	6.40 (2.51)	5.04 (2.22)
M ₄	Flonicamid 50% WG @ 4 g/10 lit Fb Emamectin benzoate 1.90% EC @ 8.5 ml/10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g/10 lit	5.94 (2.43)	6.88 (2.61)	6.40 (2.51)	3.75 (1.93)	4.00 (1.99)	3.75 (1.92)	6.40 (2.51)	6.80 (2.59)	5.49 (2.31)
M ₅	Untreated Control	6.25 (2.48)	7.19 (2.66)	10.00 (3.15)	8.75 (2.94)	9.00 (2.99)	7.50 (2.72)	10.00 (3.15)	10.50 (3.23)	8.65 (2.92)
	F Test	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG
	SE (m) ±	0.12	0.12	0.15	0.11	0.14	0.14	0.15	0.14	0.13
	CD at 5%	0.38	0.37	0.47	0.34	0.42	0.42	0.47	0.42	0.41
	CV%	11.13	9.98	12.08	10.02	11.81	13.61	12.08	10.51	11.40

Note: Figures in parentheses are corresponding square root transformation values.

Efficacy of different insecticide modules on Lady Bird beetle

Table 5: Effect of different insecticide modules on population of ladybird beetle

Mod	Treatment Details	23 July	31 July	7 Aug	16 Aug	24 Aug	1 Sept	8 Sept	16 Sept	Cumulative Average
M ₁	Imidacloprid 48% FS @ 1.25 ml/kg seed Fb Isocycloseram	1.75	1.44	1.63	1.50	1.88	1.53	2.50	2.70	1.87 (1.33)

	9.2% w/w DC @ 12 ml/10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml/10 lit	(1.29)	(1.15)	(1.25)	(1.20)	(1.33)	(1.23)	(1.57)	(1.63)	
M ₂	Thiamethoxam 30% FS @ 10 ml/kg seed Fb Tetraniliprole 18.18 SC @ 5 ml/10 lit Fb Chlorantraniliprole 9.30% + Lambda Cyhalothrin 4.60% ZC @ 4 ml/10 lit	1.50 (1.22)	1.25 (1.11)	1.50 (1.22)	1.25 (1.11)	1.63 (1.27)	1.25 (1.11)	2.20 (1.47)	2.40 (1.54)	1.62 (1.26)
M ₃	Thiamethoxam 25% WG @ 6 g/kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml/10 lit	1.38 (1.16)	1.00 (0.99)	1.38 (1.17)	0.90 (0.95)	1.00 (0.99)	1.00 (0.99)	2.00 (1.41)	2.20 (1.48)	1.36 (1.14)
M ₄	Flonicamid 50% WG @ 4 g/10 lit Fb Emamectin benzoate 1.90% EC @ 8.5 ml/10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g/10 lit	1.00 (0.99)	0.75 (0.86)	1.08 (1.03)	1.05 (1.02)	1.33 (1.14)	0.88 (0.93)	1.50 (1.22)	1.80 (1.33)	1.17 (1.07)
M ₅	Untreated Control	1.88 (1.36)	1.50 (1.22)	2.10 (1.44)	2.00 (1.40)	2.50 (1.57)	2.00 (1.41)	2.80 (1.67)	3.20 (1.78)	2.25 (1.48)
	F Test	NS	NS	NS	NS	NS	NS	NS	NS	NS
	SE (m) ±	0.10	0.08	0.09	0.08	0.12	0.12	0.10	0.09	0.10
	CD at 5%	—	—	—	—	—	—	—	—	—
	CV%	16.78	15.89	14.28	13.69	19.53	21.68	13.75	12.23	15.98

Note: Figures in parentheses are corresponding square root transformation values.

The data presented in Table 7 revealed that there was no statistically difference observed in ladybird beetle populations among the various treatment modules across different observation intervals following each spray. Observed population ranged from 1.17 to 1.87 beetles per

metre row length. However, the untreated control plots recorded numerically higher number of ladybird beetles with 2.25 beetles per metre row length.

Efficacy of different insecticide modules against Spider

Table 6: Effect of different insecticide modules on population of Spider

Mod	Treatment Details	23 July	31 July	7 Aug	16 Aug	24 Aug	1 Sept	8 Sept	16 Sept	Cumulative Average
M ₁	Imidacloprid 48% FS @ 1.25 ml/kg seed Fb Isocycloseram 9.2% w/w DC @ 12 ml/10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml/10 lit	1.80 (1.26)	1.00 (0.91)	1.44 (1.19)	1.34 (1.15)	2.88 (1.69)	1.50 (1.22)	2.88 (1.60)	3.50 (1.86)	2.04 (1.36)
M ₂	Thiamethoxam 30% FS @ 10 ml/kg seed Fb Tetraniliprole 18.18 SC @ 5 ml/10 lit Fb Chlorantraniliprole 9.30% + Lambda Cyhalothrin 4.60% ZC @ 4 ml/10 lit	2.20 (1.48)	1.25 (1.11)	1.75 (1.32)	1.25 (1.11)	2.25 (1.42)	1.88 (1.30)	3.38 (1.83)	3.80 (1.94)	2.22 (1.44)
M ₃	Thiamethoxam 25% WG @ 6 g/kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml/10 lit	2.40 (1.54)	1.53 (1.23)	1.88 (1.30)	0.75 (0.86)	1.15 (1.07)	1.38 (1.16)	2.28 (1.50)	2.80 (1.66)	1.77 (1.29)
M ₄	Flonicamid 50% WG @ 4 g/10 lit Fb Emamectin benzoate 1.90% EC @ 8.5 ml/10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g/10 lit	1.20 (1.09)	0.88 (0.93)	1.25 (1.11)	1.00 (0.99)	1.88 (1.36)	0.83 (0.91)	1.48 (1.21)	2.40 (1.54)	1.37 (1.14)
M ₅	Untreated Control	3.20 (1.78)	2.00 (1.41)	2.75 (1.65)	1.50 (1.22)	3.00 (1.72)	2.00 (1.41)	3.50 (1.86)	4.00 (1.99)	2.74 (1.63)
	F Test	NS	NS	NS	NS	NS	NS	NS	NS	NS
	SE (m) ±	0.15	0.12	0.13	0.08	0.15	0.12	0.18	0.11	0.13
	CD at 5%	—	—	—	—	—	—	—	—	—
	CV%	20.76	21.68	19.87	15.89	20.84	19.74	22.43	12.49	19.21

Note: Figures in parentheses are corresponding square root transformation values.

The results tabulated in Table 8 revealed non-significant differences among the treatment modules in respect spider population recorded at different intervals of observation after each treatment sprays. The population of spider recorded in different modules ranged between 1.37 to 2.22 spiders per metre row length. Whereas, in untreated control plots numerically higher number of spiders were observed (2.74 Spider per metre row length).

The results revealed that all the treatments under the present investigation proved less detrimental to the predatory fauna like ladybird beetle and spider in soybean ecosystem. similar findings were reported by Kambrekar et. al. (2017) [6], who reported that emamectin benzoate 1.9% EC, even when applied at double the recommended dose (850 ml ha⁻¹), did not produce any phytotoxic symptoms on soybean and had no significant adverse effect on the populations of spiders and coccinellid beetles. Shivkumar et.al. (2020) reported that, lower chemical doses specifically Tetraniliprole 480 FS @ 1.2 g/kg (T₂) and 2.4 g/kg (T₃),

alongside Imidacloprid 600 FS @ 6 g/kg (T₅) and Thiamethoxam 30% FS @ 2.4 g/kg (T₆) were found to be comparatively safer to resident natural enemies. Kambrekar (2017) [7] reported that tetraniliprole 200 SC was relatively safe to natural enemies, as the populations of predators and parasitoids remained statistically at par with the untreated control after both spray applications.

Effect of different treatment modules on yield on Soybean: The data presented in the table revealed that different insecticidal treatment modules had a significant influence on soybean yield. Among the different modules, M₂ (Thiamethoxam 30% FS @ 10 ml/kg seed followed by Tetraniliprole 18.18 SC @ 5 ml/10 L followed by Chlorantraniliprole 9.30% + Lambda-cyhalothrin 4.60% ZC @ 4 ml/10 L) recorded the highest yield of 3.20 kg/plot, corresponding to 15.92 q/ha. It was followed by M₁, which recorded 2.65 kg/plot and 13.19 q/ha. Module M₃ recorded a yield of 10.95 q/ha, followed by M₄ (9.20 q/ha), whereas

the lowest yield of 6.71 q/ha was recorded in the untreated control (M5). The higher yield obtained in M2 and M1 may be attributed to their effective and sustained management of major insect pests of soybean, resulting in better protection of the crop and consequently higher seed yield.

These findings are in agreement with Kambrekar (2020) [8], who reported that Chlorantraniliprole 9.3% + Lambda-cyhalothrin 4.6% ZC @ 200 ml ha⁻¹ resulted in the highest soybean yield of 17.57 q/ha and 18.68 q ha⁻¹ during 2016 and 2017, respectively. Priya et.al. (2024) [14] revealed that Chlorantraniliprole 10% + lambda-cyhalothrin 5% ZC (Ampligo 150 ZC) @ 200 ml ha⁻¹ recorded the highest seed yield of 19.30 and 19.01 q ha⁻¹ during 2021 and 2022, respectively. Manjanaik *et al.* (2017) [12] reported that thiamethoxam 30 FS @ 10 ml kg⁻¹ seed followed by thiamethoxam 25 WG @ 0.40 g l⁻¹ at 30 DAG recorded the highest grain yield of 1794.48 kg ha⁻¹, followed by imidacloprid 48 FS @ 1.25 ml kg⁻¹ seed followed by imidacloprid 17.8 SL @ 0.50 ml l⁻¹, which recorded 1678.89 kg ha⁻¹.

Economics: The data on economics of treatment in table and revealed that module M2 (Thiamethoxam 30% FS @ 10 ml /kg seed Fb Tetranilliprole 18.18 SC @ 5 ml /10 lit Fb Chlorantranilliprole 9.30% + Lambda Cyhalothrin 4.60% ZC @ 4 ml / 10 lit.) was found to be most economical module with ICBR of 1:6.89 and net profit of RS.42,854 /ha

followed by module 3 (Thiamethoxam 25% WG @ 6 g /kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml /10 lit) with registered ICBR of 1: 3.40. Then module 1 (Imidacloprid 48% FS @ 1.25 ml/kg seed Fb Isocycloseram 9.2%w/w DC @ 12 ml / 10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml / 10 lit) with ICBR of 1: 3.13 and module M4 (Flonicamid 50% WG @ 4 g/10 lit Fb Emamectin benzoate 1.90% EC @ 8.5 ml /10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g /10 lit) having ICBR of 1:1.26.

Present investigation of the research work is collaborated with Manjanaik *et. al.* (2023) [12], revealed that thiamethoxam- based seed treatment and foliar application against *Melanagromyza sojae* comprising of thiamethoxam 30 FS @ 10 ml kg⁻¹ seed followed by foliar application of thiamethoxam 25 WG @ 0.40 g l⁻¹ at 30 DAG was the most cost-effective, recording the highest benefit-cost ratio of 1:4.22. Priya *et al.* (2024) [14], who observed that chlorantraniliprole 10% + lambda-cyhalothrin 5% ZC @ 200 ml/ha recorded the highest benefit-cost ratio of 4.63 along with the highest net returns and seed yield in soybean. Makani *et.al.* (2024) [11] in a soybean study against *Spodoptera litura*, where chlorantraniliprole 10 + lambda-cyhalothrin 5 ZC @ 0.006% recorded the highest ICBR of 1:8.8.

Table 7: Incremental cost benefit ratio of various treatment modules

Mod. No.	Treatment	Quantity of insecticides Dose/500 lit of water	No. of sprays	Cost of insecticides (Rs/ha)	Labour and sprayer charges (Rs/ha)	Cost of plant protection (Rs/ha) (A)	Yield of soybean (q/ha)	Increase in yield over control (q/ha)	Value of increase in yield over control (Rs) @ Rs 5328 (B)	Net gain over control (C) (B- A)	ICBR (C/A)	Rank
M1	Imidacloprid 48% FS @ 1.25 ml/kg seed Fb Isocycloseram 9.2% w/w DC @ 12 ml/10 lit Fb Thiamethoxam 12.60% + Lambda Cyhalothrin 9.50% ZC @ 2.5 ml/10 lit	94 ml + 600 ml + 125 ml	3	6108	2250	8358	13.19	6.48	34525	26167	1:3.13	3
M2	Thiamethoxam 30% FS @ 10 ml/kg seed Fb Tetranilliprole 18.18 SC @ 5 ml/10 lit Fb Chlorantraniliprole 9.30% + Lambda Cyhalothrin 4.60% ZC @ 4 ml/10 lit	750 ml + 250 ml + 200 ml	3	3966	2250	6216	15.92	9.21	49070	42854	1:6.89	1
M3	Thiamethoxam 25% WG @ 6 g/kg seed Fb Indoxacarb 15.80% EC @ 7 ml/10 lit Fb Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @ 7 ml/10 lit	450 g + 350 ml + 350 ml	3	2878	2250	5128	10.95	4.24	22590	17462	1:3.40	2
M4	Flonicamid 50% WG @ 4 g/10 lit Fb Emamectin benzoate 1.90% EC @ 8.5 ml/10 lit Fb Acetamiprid 25% + Bifenthrin 25% WG @ 5 g/10 lit	200 g + 425 ml + 250 ml	3	3615	2250	5865	9.20	2.49	13266	7401	1:1.26	4
M5	Untreated control	—	—	—	—	—	6.71	—	—	—	—	—

1) Labour charges for one spray /ha @Rs350/Labour /Day,2) Spray pump charges /ha Rs 50/day /Pump,3) Price of Soybean Rs 5328/qtl. Cost of Insecticides:imidacloprid 48% FS@Rs 3600 Rs/L,Isocycloseram 9.2% w/w DC 9083/L,Thiamethoxam 12.60% +Lambda cyhalothrin 9.50% zc Rs 2550 /L, Thiamethoxam 30% FS @Rs 1250 /L, Tetranilliprole 18.18 SC @RS 9876/L,Chlorantranilliprole

9.30% + Lambda cyhalothrin 4.60% ZC @Rs 2799/L, Thiamethoxam 25% WG @RS 2048/L, Indoxacarb 15.80% EC @RS 3392/L, Betacyfluthrin 8.49% + Imidacloprid 19.81% w/w OD @Rs 2200/L,Flonicamid 50% WG @RS 10,798 /L, Emmamectin benzoate 1.90% EC @RS 1482 /L,Acetamiprid 25% + Bifenthrin 25% WG @ RS 3300 /L.

Conclusion

The present investigation revealed that all the tested treatment modules were significantly more effective than the untreated control in managing major insect pests of soybean including stem fly and girdle beetle. Among the modules, Module 2 which primarily consisted of a seed treatment and two foliar sprays consistently recorded the lowest population of stem fly and girdle beetle of soybean and found statistically at par with module M1, M3 and M4. In terms of natural enemies such as lady bird beetle and spider all the insecticide treatment modules were found to be safe and non - disruptive, as no significant differences were observed among the modules compared to the untreated control. Regarding yield performance, all the modules outperformed the untreated control, with module 2 producing the higher soybean yield (15.92 q/ha), followed by M1 which recorded the yield of 13.19 q/ha. While Module M3 recorded yield of 10.95 q/ha followed by Module 4 which recorded 9.20q/ha. The Untreated control recorded lowest yield which is 6.71q/ha. From an economic standpoint, Module 2 emerged as the most cost effective treatment, recording the highest incremental cost benefit ratio (ICBR of 1:6.89) and a net profit of RS 42, 854/ha. This was followed by module 3 (ICBR 1: 3.40). While module 1 and 4 also showed favourable ICBR values of 1:3.13 and 1:1.26 respectively, confirming their practical viability.

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