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IMPACT OF BIORATIONAL INSECTICIDES ON THE POPULATION OF NATURAL ENEMIES IN COWPEA UNDER FIELD CONDITIONS

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ABSTRACT

The present investigation was carried out in the Instructional Farm of S.K.N. College of Agriculture, Jobner (Jaipur), Rajasthan, India, during the *Kharif* season of 2024 and 2025 under field conditions. The toxicity of biorational insecticides was assessed on the basis of the population of natural enemies. Since the ladybird beetle and spiders have been recorded as the major natural enemies in the cowpea ecosystem. The pooled data on the toxic impact of biorational insecticides on the population of natural enemies revealed that all the insecticides were found to be more or less toxic up to three days of treatment. The minimum population of natural enemies was recorded in fipronil 5 SC and spiromesifen 22.9 SC, which proved highly toxic. The flubendiamide 39.35 SC, chlorantraniliprole 18.5 SC, spinosad 45 SC and emamectin benzoate 5 SG treated plots resulted in the middle order to express toxic effects on the natural enemies. The maximum population of natural enemies was recorded in NSKE 5%, and azadirachtin 0.03 EC proved least toxic, followed by *M. anisopliae* 1.15 WP and *L. lecanii 1.15 WP*. These treatments were statistically at par with each other.
***Keywords* :** Biorational, natural enemies, toxicity, field conditions.

Introduction

Cowpea, *Vigna unguiculata* (L.) Walp. is one of the important *kharif* pulse crops in India, referred to as Lobia. It serves as a valuable source of protein, significantly more than cereals, which is important for nutritional security, especially in vegetarian diets and rural households. It has been referred to as "Poor man's meat" because of its high protein content, *viz.*, 20- 25 per cent (Sabale *et al.*, 2018). In recent years, it has been included in the food security programme of different countries. In India, pulses occupied nearly 27.72 million hectares area with a production of 25.68 million tonnes during the year 2024-2025. Cowpea covered about 1.5 million hectares with an annual production of 0.5 million tonnes, contributing marginally to the total pulse basket (Anonymous, 2025a). The area under pulses in Rajasthan was 5.41 million hectares, with the production to the tune of 3.93 million tonnes with an average productivity of 727 kg/ha; whereas, cowpea covered an area of 0.45 lakh ha with a production of 0.39 lakh tonnes and productivity of 857 kg/ha (Anonymous, 2025b). The major growing districts of Rajasthan are Sikar, Jhunjhunu, Nagaur, Jodhpur, Jalore, Ajmer, Jaipur, Churu, Pali, Bikaner and Barmer.

The losses in grain or foliage of cowpea range from 20 to 100 per cent due to field insect pests. As many as 21 insect pests of different groups were observed on cowpea during the summer and *kharif* seasons. Among various insect pests, cowpea aphid, *Aphis craccivora* Koch., leafhopper, *Emposca kerri* Pruthi, whitefly, *Bemisia tabaci* Genn., pod borer, *Helicoverpa armigera* Hubner and spotted pod borer, *Maruca vitrata* Fabricius are potential pests causing considerable damage (Choudhary *et al.*, 2021 and Yadav *et al.*, 2025). Because natural enemies are key to controlling pest populations, any harm to their survival or activity can disturb the ecological balance in crop systems. Understanding how biorational insecticides impact these beneficial species is therefore crucial for developing sustainable and effective pest management practices.

Materials and Methods

The experiment was laid out in a simple Randomized block design (RBD) with eleven treatments, including an untreated control (Table 2.1) and each treatment was replicated thrice. The plot size was 3 m x 2 m^2 with row-to-row and plant-to-plant distances of 30 cm and 10 cm, respectively. The variety CPD-119 was sown in the 2nd week of July, 2024 and 2025. The recommended package of practices was followed to raise the crop.

Table 1: Test insecticides used for treatment imposition

Tr. No.	Treatment	Dose (g or ml a.i./ ha)	Formulation dose (gm or ml/ ha)	Conc. (%)/ Doses (gm or ml)
T_1	Chlorantraniliprole 18.5 SC	30	160	0.006 %
T_2	Emamectin benzoate 5 SG	10	200	0.002 %
T_3	Spinosad 45 SC	75	165	0.014 %
T_4	Flubendiamide 39.35 SC	48	120	0.009 %
T_5	Spiromesifen 22.9 SC	120	524	0.024 %
T_6	Azadirachtin 0.03 EC	-	2500	5 ml/L
T_7	NSKE (lab prepared)	-	-	5 ml/L
T_8	*Metarhizium anisopliae* 1.15 WP (2 x 10^8 CFU/gm)	-	2500	5 g/L
T_9	*Lecanicillium. lecanii* 1.15 WP (2 x 10^8 CFU/gm)	-	2500	5 g/L
T_{10}	Fipronil 5 SC	50	1000	0.01%
T_{11}	Untreated control	-	-	-

NSKE = Neem seed kernel extract

The population of ladybird beetles and spider on cowpea crop were recorded from five randomly selected and tagged plants in each plot at a weekly interval from their appearance till harvesting of the crop. The observation was recorded one day before application (pre-treatment population) and one, three, seven and ten days after application (post-treatment population) of insecticides in both the sprays. The per cent reduction in the population of major insect pests was calculated by using Henderson and Tilton's (1955) formula, which is a modification of Abbott's formula (1925) and subjected to analysis of variance.

$$\textbf{Per cent reduction} = \left(1 - \frac{\textbf{Ta x Cb}}{\textbf{Tb x Ca}}\right) \textbf{x 100}$$

Where,

Ta = Insect population in treated plants after treatment

Tb = Insect population in treated plants before treatment

Ca = Insect population in the control plot after treatment

Cb = Insect population in control plots before treatment

The data were subjected to statistical analysis after transforming the percentage reduction in the insect pests population of cowpea into angular transformation values (Bliss, 1937).

Plate 1 : Spider on cowpea crop

Plate 2 : Different species of lady bird beetles cowpea crop

Results and Discussion

Impact of biorational insecticides on the population of coccinellids *Kharif*, 2024

The data on Ladybird beetle population during the *Kharif*, 2024, are presented in Table 2.

First spray

One day after spraying, fipronil recorded the highest reduction in coccinellid population (69.21%), followed by spiromesifen (63.75%). Flubendiamide (56.62%) and chlorantraniliprole (54.42%) were statistically at par and exhibited high toxicity. Emamectin benzoate (45.36%) and spinosad (44.52%) showed moderate toxicity, whereas *L. lecanii* (26.58%) and *Metarhizium anisopliae* (24.42%) were comparatively safer and at par with each other. The lowest reduction was recorded in azadirachtin (17.29%) and NSKE (12.74%), indicating their relative safety to coccinellids.

A similar trend of per cent reduction in coccinellid population after three and seven days of insecticidal spray was observed.

At ten days after spraying, all treatments differed significantly from the untreated control. The highest reduction in coccinellid population was observed in fipronil and spiromesifen, with 55.82 and 44.77 per cent reduction, respectively. It was followed by flubendiamide (38.36%) and chlorantraniliprole (36.49%), which were statistically comparable. Emamectin benzoate (29.12%) and spinosad (27.81%) showed toxicity of a moderate degree. *L. lecanii* (19.52%) and *M. anisopliae* (17.26%) were at par, whereas azadirachtin (12.31%) and NSKE (8.54%) recorded the lowest reduction.

The mean data also followed a similar trend, wherein fipronil (68.06%) was the most toxic treatment. The least reduction was recorded in azadirachtin (18.47%) and NSKE (13.56%), indicating their safer effect on coccinellids. In descending order, it was followed by spiromesifen (60.24%), while flubendiamide (53.83%) and chlorantraniliprole (52.01%) were equal at the statistical level. Emamectin benzoate (43.64%) and spinosad (42.51%) showed moderate toxicity. Within biopesticides, *L. lecanii* (27.77%) and *M. anisopliae* (25.69%) were at par with each other.

Second spray

A similar trend of per cent reduction in coccinellid population after second insecticidal spray was observed.

Kharif, 2025

The data on Ladybird beetle population during the *Kharif*, 2025, are depicted in Table 4.17.

First spray

One day after spraying, fipronil caused the highest reduction in coccinellid population (67.13%), followed by spiromesifen (61.84%). Flubendiamide (54.92%) and chlorantraniliprole (52.79%) were statistically at par, while emamectin benzoate (44.00%) and spinosad (43.18%) showed moderate toxicity. Among biopesticides, L. lecanii (25.78%) and M. anisopliae (23.69%) were comparable, whereas azadirachtin (16.77%) and NSKE (12.36%) were the safest treatments.

Three days after spraying, a similar trend was observed, with fipronil (73.10%) remaining the most toxic treatment, followed by spiromesifen (65.10%). Flubendiamide (59.98%) and chlorantraniliprole (57.87%) were statistically at par, while emamectin benzoate (50.16%) and spinosad (48.52%) exhibited moderate toxicity. Lower reductions were recorded with L. lecanii (34.56%), M. anisopliae (32.53%), azadirachtin (23.60%) and NSKE (17.91%).

Table 2 : Impact of biorational insecticides on coccinellids during *kharif*, 2024

S. No.	Treatments	Conc.	Per cent reduction in coccinellid population days after spray: I spray 1 DAS	3 DAS	7 DAS	10DAS	Mean	II Spray 1 DAS	3 DAS	7 DAS	10DAS	Mean
1.	Chlorantraniliprole 18.5 SC	0.006%	54.42 (47.54)	59.66 (50.57)	57.45 (49.28)	36.49 (37.16)	52.01 (46.15)	56.13 (48.52)	62.64 (52.32)	60.32 (50.96)	38.31 (38.24)	54.35 (47.50)
2.	Emamectin benzoate 5 SG	0.002%	45.36 (42.34)	51.71 (45.98)	48.36 (44.06)	29.12 (32.66)	43.64 (41.34)	46.39 (42.93)	54.30 (47.47)	50.78 (45.45)	30.58 (33.57)	45.51 (42.43)
3.	Spinosad 45 SC	0.014%	44.52 (41.85)	50.02 (45.01)	47.67 (43.66)	27.81 (31.83)	42.51 (40.69)	44.71 (41.96)	52.52 (46.44)	50.05 (45.03)	29.20 (32.71)	44.12 (41.62)
4.	Flubendiamide 39.35 SC	0.009%	56.62 (48.80)	61.83 (51.84)	58.49 (49.89)	38.36 (38.27)	53.83 (47.19)	58.44 (49.86)	64.92 (53.68)	61.41 (51.60)	40.28 (39.40)	56.26 (48.60)
5.	Spiromsifen 22.9 SC	0.024%	63.75 (52.98)	67.11 (55.01)	65.31 (53.92)	44.77 (42.00)	60.24 (50.91)	64.59 (53.48)	70.47 (57.08)	68.58 (55.91)	47.01 (43.29)	62.66 (52.34)
6.	Azadirachtin 0.03 EC	5 ml/L	17.29 (24.57)	24.33 (29.55)	19.94 (26.52)	12.31 (20.54)	18.47 (25.45)	19.28 (26.05)	25.55 (30.36)	20.94 (27.23)	12.93 (21.07)	19.68 (26.33)
7.	NSKE	5 ml/L	12.74 (20.91)	18.46 (25.45)	14.51 (22.39)	8.54 (16.99)	13.56 (24.61)	14.63 (22.49)	19.38 (26.12)	15.24 (22.98)	8.97 (17.43)	14.56 (22.43)
8.	*Metarhizum anispopliae* 1.15 WP	5 g/L	24.42 (29.61)	33.54 (35.39)	27.54 (31.65)	17.26 (24.55)	25.69 (30.45)	27.06 (31.35)	35.22 (36.40)	28.92 (32.53)	18.12 (25.19)	27.33 (31.52)
9.	*Lecanicillium lecani* 1.15 WP	5 g/L	26.58 (31.03)	35.63 (36.65)	29.33 (32.79)	19.52 (26.22)	27.77 (31.80)	28.33 (32.16)	37.41 (37.71)	30.80 (33.71)	20.50 (26.92)	29.26 (32.75)
10.	Fipronil 5 SC	0.01%	69.21 (56.30)	75.36 (60.24)	71.84 (57.95)	55.82 (48.34)	68.06 (55.59)	71.15 (57.51)	79.13 (62.82)	75.43 (60.29)	58.61 (49.96)	71.08 (57.47)
11.	Untreated Control	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm±		1.13	1.09	1.34	1.23	1.15	1.22	1.15	1.36	1.31	1.24
	CD at 5%		3.25	3.15	3.96	3.54	3.38	3.54	3.39	3.99	3.78	3.45

PTP = Pre-treatment population, DAS: Days after spray. Figures in parentheses are angular transformed values

Table 3 : Impact of biorational insecticides on coccinellids during *kharif*, 2025

S. No.	Treatments	Conc.	Per cent reduction in coccinellid population days after spray: I spray 1 DAS	3 DAS	7 DAS	10DAS	Mean	II Spray 1 DAS	3 DAS	7 DAS	10DAS	Mean
1.	Chlorantraniliprole 18.5 SC	0.006%	52.79 (46.60)	57.87 (49.53)	55.73 (48.29)	35.40 (36.51)	50.45 (45.26)	55.59 (48.21)	60.94 (51.32)	58.68 (50.00)	37.28 (37.63)	53.12 (46.79)
2.	Emamectin benzoate 5 SG	0.002%	44.00 (41.55)	50.16 (45.09)	46.91 (43.23)	28.25 (32.11)	42.33 (40.59)	46.33 (42.90)	52.82 (46.62)	49.40 (44.66)	29.75 (33.05)	44.58 (41.89)
3.	Spinosad 45 SC	0.014%	43.18 (41.08)	48.52 (44.15)	46.24 (42.84)	26.98 (31.29)	41.23 (39.95)	45.47 (42.40)	51.09 (45.62)	48.69 (44.25)	28.41 (32.21)	43.42 (41.22)
4.	Flubendiamide 39.35 SC	0.009%	54.92 (47.82)	59.98 (50.76)	56.74 (48.87)	37.21 (37.59)	52.21 (46.27)	57.83 (49.50)	63.16 (52.63)	59.75 (50.62)	39.18 (38.75)	54.98 (47.86)
5.	Spiromsifen 22.9 SC	0.024%	61.84 (51.85)	65.10 (53.79)	63.35 (52.74)	43.43 (41.22)	58.43 (49.85)	65.12 (53.80)	68.55 (55.89)	66.71 (54.76)	45.73 (42.55)	61.53 (51.66)
6.	Azadirachtin 0.03 EC	5 ml/L	16.77 (24.17)	23.60 (29.06)	19.34 (26.09)	11.94 (20.21)	17.91 (25.04)	17.66 (24.85)	24.85 (29.90)	20.36 (26.82)	12.57 (20.77)	18.86 (25.74)
7.	NSKE	5 ml/L	12.36 (20.58)	17.91 (25.04)	14.07 (22.03)	8.28 (16.72)	13.16 (21.27)	13.02 (21.15)	18.86 (25.74)	14.82 (22.64)	8.72 (17.18)	13.86 (21.85)
8.	*Metarhizum anispopliae* 1.15 WP	5 g/L	23.69 (29.13)	32.53 (34.77)	26.71 (31.12)	16.74 (24.15)	24.92 (29.95)	24.94 (29.96)	34.25 (35.82)	28.13 (32.03)	17.63 (24.83)	26.24 (30.81)
9.	*Lecanicillium lecani* 1.15 WP	5 g/L	25.78 (30.51)	34.56 (36.01)	28.45 (32.23)	18.93 (25.79)	26.93 (31.26)	27.15 (31.40)	36.39 (37.10)	29.96 (33.19)	19.93 (26.51)	28.36 (32.18)
10.	Fipronil 5 SC	0.01%	67.13 (55.02)	73.10 (58.76)	69.68 (56.59)	54.15 (47.38)	66.02 (54.34)	70.69 (57.22)	76.97 (61.32)	73.37 (58.93)	57.02 (49.04)	69.51 (56.49)
11.	Untreated Control	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm±		1.24	1.03	1.32	1.22	1.06	1.16	1.11	1.29	1.20	1.03
	CD at 5%		3.58	3.01	3.76	3.47	3.16	3.38	3.18	3.76	3.55	2.96

PTP = Pre-treatment population, DAS: Days after spray. Figures in parentheses are angular transformed values

Table 4 : Impact of biorational insecticides on coccinellids (Pooled data of *kharif*, 2024 and 2025)

S. No.	Treatments	Conc.	I spray 1 DAS	I spray 3 DAS	I spray 7 DAS	I spray 10DAS	I spray Mean	II Spray 1 DAS	II Spray 3 DAS	II Spray 7 DAS	II Spray 10DAS	II Spray Mean
1.	Chlorantraniliprole 18.5 SC	0.006%	53.61 (47.07)	58.77 (50.05)	56.59 (48.79)	35.95 (36.84)	51.23 (45.70)	55.86 (48.37)	61.79 (51.82)	59.50 (50.48)	37.80 (37.94)	53.74 (47.14)
2.	Emamectin benzoate 5 SG	0.002%	44.68 (41.95)	50.94 (45.54)	47.64 (43.64)	28.69 (32.38)	42.98 (40.97)	46.36 (42.91)	53.56 (47.04)	50.09 (45.05)	30.17 (33.31)	45.04 (42.16)
3.	Spinosad 45 SC	0.014%	43.85 (41.47)	49.27 (44.58)	46.96 (43.25)	27.40 (31.56)	41.87 (40.32)	45.09 (42.18)	51.81 (46.03)	49.37 (44.64)	28.81 (32.46)	43.77 (41.42)
4.	Flubendiamide 39.35 SC	0.009%	55.77 (49.31)	60.91 (51.30)	57.62 (49.38)	37.79 (37.93)	53.02 (46.73)	58.14 (49.68)	64.04 (53.15)	60.58 (51.11)	39.73 (39.07)	55.62 (48.23)
5.	Spiromsifen 22.9 SC	0.024%	62.80 (52.41)	66.11 (54.40)	64.33 (53.33)	44.10 (41.61)	59.33 (50.38)	64.86 (53.64)	69.51 (56.48)	67.65 (55.33)	46.37 (42.92)	62.10 (52.00)
6.	Azadirachtin 0.03 EC	5 ml/L	17.03 (24.37)	23.97 (29.31)	19.64 (26.31)	12.13 (20.38)	18.19 (25.25)	18.47 (25.45)	25.20 (30.13)	20.65 (27.03)	12.75 (20.92)	19.27 (26.04)
7.	NSKE	5 ml/L	12.55 (20.75)	18.19 (25.24)	14.29 (22.21)	8.41 (16.86)	13.36 (21.44)	13.83 (21.83)	19.12 (25.93)	15.03 (22.81)	8.85 (17.30)	14.21 (22.14)
8.	*Metarhizum anispopliae* 1.15 WP	5 g/L	24.06 (29.37)	33.04 (35.08)	27.13 (31.39)	17.00 (24.35)	25.30 (30.20)	26.00 (30.66)	34.74 (36.11)	28.53 (32.28)	17.88 (25.01)	26.78 (31.17)
9.	*Lecanicillium lecani* 1.15 WP	5 g/L	26.18 (30.77)	35.10 (36.33)	28.89 (32.51)	19.23 (26.01)	27.35 (31.53)	27.74 (31.78)	36.90 (37.41)	30.38 (33.45)	20.22 (26.72)	28.81 (32.46)
10.	Fipronil 5 SC	0.01%	68.17 (55.65)	74.23 (59.49)	70.76 (57.27)	54.99 (47.86)	67.04 (54.96)	70.92 (57.37)	78.05 (62.06)	74.40 (59.60)	57.82 (49.50)	70.30 (56.97)
11.	Untreated Control	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm±		1.24	1.06	1.33	1.19	0.93	1.21	1.16	1.28	1.23	1.02
	CD at 5%		3.51	3.08	3.86	3.49	2.72	3.54	3.37	3.76	3.60	3.02

Per cent reduction in coccinellid population days after spray

PTP = Pre-treatment population, DAS: Days after spray. Figures in parentheses are angular transformed value

The mean data also followed a similar pattern. Fipronil recorded the highest mean reduction in coccinellid population (66.02%), followed by spiromesifen (58.43%). Flubendiamide (52.21%) and chlorantraniliprole (50.45%) were statistically at par, whereas emamectin benzoate (42.33%) and spinosad (41.23%) caused moderate adverse effects. Among biopesticides, L. lecanii (26.93%) and M. anisopliae (24.92%) were comparatively safer, while azadirachtin (17.91%) and NSKE (13.16%) were found to be the least harmful to coccinellids.

Second spray

A similar trend of per cent reduction in coccinellid population after the second insecticidal spray was observed.

Pooled data *Kharif, 20*24 and 2025

The pooled data on the evaluation of the toxic effects of biorational insecticides on the ladybird beetle population during the *Kharif* season in 2024 and 2025 are presented in Table 4.19 and Fig. 4.8.

First spray

Following insecticidal application, fipronil consistently recorded the highest reduction in coccinellid population, with reductions of 68.17, 74.23, 70.76 and 54.99 per cent at 1, 3, 7 and 10 days after spraying, respectively, followed by spiromesifen (62.80, 66.11, 64.33 and 44.10%). Flubendiamide and chlorantraniliprole remained statistically at par throughout the observation period and exhibited comparatively high toxicity. Emamectin benzoate and spinosad showed moderate adverse effects on coccinellids.

Among the biopesticides, *L. lecanii* and *Metarhizium anisopliae* were statistically similar and comparatively safer than the synthetic insecticides. The lowest reduction in coccinellid population was consistently recorded with azadirachtin and NSKE, indicating their relative safety to the predator.

The mean data also followed a similar trend, wherein fipronil recorded the highest reduction in coccinellid population (67.04%), followed by spiromesifen (59.33%). Flubendiamide (53.02%) and chlorantraniliprole (51.23%) were statistically at par, while emamectin benzoate (42.98%) and spinosad (41.87%) exhibited moderate toxicity. Among the biopesticides, *L. lecanii* (27.35%) and *Metarhizium anisopliae* (25.30%) were statistically similar, whereas azadirachtin (18.19%) and NSKE (13.36%) recorded the lowest reduction in coccinellid population, indicating their comparatively safer nature towards coccinellids.

Second spray

A similar trend of per cent reduction in coccinellid population after second insecticidal spray was observed.

Impact of biorational insecticides on the population of the spiders

***Kharif*, 2024**

The data on the per cent reduction in the spider population during the *Kharif* 2024 are presented in Table 4.17

First spray

Following the first spray, fipronil consistently recorded the highest reduction in spider population, with reductions of 64.64, 70.38, 67.10 and 52.14 per cent at 1, 3, 7 and 10 days after spraying, respectively, followed by spiromesifen (59.55, 62.68, 61.00 and 41.82%). Flubendiamide and chlorantraniliprole remained statistically at par throughout the observation period and exhibited comparatively high toxicity. Emamectin benzoate and spinosad showed moderate toxic effects on spiders.

Among the biopesticides, *L. lecanii* and *Metarhizium anisopliae* were comparatively less toxic and statistically similar. The lowest reduction in spider population was consistently recorded with azadirachtin and NSKE, indicating their relative safety to spiders.

The overall mean data of the first spray followed a similar trend, with fipronil recording the highest reduction in spider population (63.57%), followed by spiromesifen (56.26%). Flubendiamide (50.28%) and chlorantraniliprole (48.57%) were statistically at par, while emamectin benzoate (40.76%) and spinosad (39.70%) exhibited moderate toxicity. Among the biopesticides, *L. lecanii* (25.94%) and *Metarhizium anisopliae* (23.99%) were comparatively safer, whereas azadirachtin (17.25%) and NSKE (12.67%) recorded the lowest reduction in spider population, indicating their safer nature towards spiders.

Second spray

A similar trend of per cent reduction in spider population after second insecticidal spray was observed.

***Kharif*, 2025**

The data on per cent reduction in the spider population during the *kharif* 2025, are presented in Table 4.17

First spray

One day after the initial spray, the greatest reduction in spider population was observed with fipronil, with 61.94 per cent. It was followed by spiromesifen (57.06%). The next toxic group include flubendiamide (50.68%) and chlorantraniliprole (48.70%), which were statistically similar and exhibited relatively high toxicity. Moderate effects were recorded with emamectin benzoate (40.59%) and spinosad (39.84%). Lower toxicity was noted for *L. lecanii* (23.79%) and *M. anisopliae* (21.84%), while azadirachtin (15.47%) and NSKE (11.40%) were the least harmful to spiders.

Three, seven and ten days after spraying, fipronil consistently recorded the highest reduction in spider population (67.43, 64.29 and 49.96%, respectively), followed by spiromesifen (60.05, 58.45 and 40.07%). Flubendiamide and chlorantraniliprole remained statistically at par throughout the observation period and exhibited comparatively high toxicity. Emamectin benzoate and spinosad showed moderate adverse effects on spiders.

Among the biopesticides, *L. lecanii* and *Metarhizium anisopliae* were comparatively less toxic and statistically similar, whereas azadirachtin and NSKE consistently recorded the lowest reduction in spider population, indicating their relative safety to spiders.

The overall mean data followed a similar trend, with fipronil recording the highest reduction in spider population (60.91%), followed by spiromesifen (53.91%). Flubendiamide (48.17%) and chlorantraniliprole (46.54%) were statistically at par, while emamectin benzoate (39.05%) and spinosad (38.04%) exhibited moderate toxicity. Among the biopesticides, *L. lecanii* (24.85%) and *Metarhizium anisopliae* (22.98%) were comparatively safer, whereas azadirachtin (16.53%) and NSKE (12.14%) recorded the lowest reduction in spider population, indicating their safer nature towards spiders.

Second spray

A similar trend of per cent reduction in spider population after second insecticidal spray was observed.

Pooled data *Kharif*, 2024 and 2025

The pooled data on the evaluation of the toxic effects of biorational insecticides on the spider population during the *kharif* season in 2024 and 2025 are presented in Table 4.19 and Fig. 4.8.

First spray

Following the first spray, fipronil consistently recorded the highest reduction in spider population, with reductions of 63.29, 68.91, 65.70 and 51.05 per cent at 1, 3, 7 and 10 days after spraying, respectively, followed by spiromesifen (58.31, 61.37, 59.73 and 40.95%). Flubendiamide and chlorantraniliprole remained statistically at par throughout the observation period and exhibited comparatively high toxicity. Emamectin benzoate and spinosad caused moderate adverse effects on spiders.

Among the biopesticides, *L. lecanii* and *Metarhizium anisopliae* were comparatively less toxic and statistically similar. The lowest reduction in spider population was consistently recorded with azadirachtin and NSKE, indicating their relative safety to spiders.

The pooled mean data also followed a similar trend, wherein fipronil recorded the highest reduction in spider population (62.24%), followed by spiromesifen (55.09%). Flubendiamide (49.23%) and chlorantraniliprole (47.55%) were statistically at par, while emamectin benzoate (39.91%) and spinosad (38.87%) exhibited moderate toxicity. Among the biopesticides, *L. lecanii* (25.40%) and *Metarhizium anisopliae* (23.49%) were comparatively safer, whereas azadirachtin (16.89%) and NSKE (12.40%) recorded the lowest reduction in spider population, indicating their safer nature towards spiders.

Second spray

A similar trend of per cent reduction in spider population after the second insecticidal spray was observed.

The descending order of toxicity of insecticides against natural enemies was: fipronil > spiromesifen > flubendiamide > chlorantraniliprole > emamectin benzoate > spinosad > *L. lecanii* > *M. anisopliae* > azadirachtin > NSKE.

The pooled data on the toxic impact of biorational insecticides on the population of natural enemies revealed that all the insecticides were found to be more or less toxic up to three days of treatment. The minimum population of natural enemies was recorded in fipronil 5 SC and spiromesifen 22.9 SC, which proved highly toxic. The present findings are in agreement with those of Sharma *et al.* (2022), who observed that fipronil was harmful to natural enemies.

The flubendiamide 39.35 SC, chlorantraniliprole 18.5 SC, spinosad 45 SC and emamectin benzoate 5 SG treated plots resulted in the middle order to express toxic effects on the natural enemies. These results were corroborated by the findings of Pavithra *et al.* (2022), Sharma *et al.* (2022) and Das *et al.* (2025), who reported that these insecticides were toxic to natural enemies. Dhaka (2020), Dharmanna and Naik (2022) and Singh (2022) reported that spinosad and emamectin benzoate proved safer to natural enemies. Sireesha *et al.* (2022) reported that chlorantraniliprole and spinosad were less toxic.

The maximum population of natural enemies was recorded in NSKE 5% and azadirachtin 0.03 EC proved least toxic, followed by *M. anisopliae* 1.15 WP and *L. lecanii 1.15 WP*. These treatments were statistically at par with each other. These findings are in agreement with that of Singh *et al.* (2022), Dwivedi and Singh (2022), Thakur *et al. (*2023) and Das *et al.* (2025), who reported that azadirachatin, NSKE 5%, *L. lecanii* and *M. anisopliae* are relatively safer for natural enemies. Lawrence *et al.* (2022) and Zadda and Vijayaraghavan (2025) reported that neem-based insecticides were found to be safer than chemical insecticides

Table 5 : Impact of biorational insecticides on spiders during *Kharif*, 2024.

S. No.	Treatments	Conc.	I spray 1 DAS	I spray 3 DAS	I spray 7 DAS	I spray 10DAS	I spray Mean	II Spray 1 DAS	II Spray 3 DAS	II Spray 7 DAS	II Spray 10DAS	II Spray Mean
			Per cent reduction in spider population days after spray									
1.	Chlorantraniliprole 18.5 SC	0.006%	50.83 (45.48)	55.72 (48.28)	53.66 (47.10)	34.07 (35.71)	48.57 (44.18)	53.74 (47.14)	58.91 (50.13)	56.73 (48.87)	36.02 (36.88)	51.35 (45.77)
2.	Emamectin benzoate 5 SG	0.002%	42.37 (40.61)	48.29 (44.02)	45.18 (42.23)	27.20 (31.44)	40.76 (39.68)	44.79 (42.01)	51.05 (45.60)	47.76 (43.72)	28.76 (32.43)	43.09 (41.03)
3.	Spinosad 45 SC	0.014%	41.59 (40.16)	46.72 (43.12)	44.52 (41.85)	25.98 (30.64)	39.70 (39.06)	43.97 (41.54)	49.39 (44.65)	47.07 (43.32)	27.47 (31.61)	41.98 (40.38)
4.	Flubendiamide 39.35 SC	0.009%	52.90 (46.66)	57.76 (49.46)	54.64 (47.66)	35.82 (36.76)	50.28 (45.16)	55.92 (48.40)	61.07 (51.40)	57.77 (49.47)	37.87 (37.98)	53.16 (46.81)
5.	Spiromsifen 22.9 SC	0.024%	59.55 (50.51)	62.68 (52.35)	61.00 (51.35)	41.82 (40.29)	56.26 (48.60)	62.95 (52.51)	66.27 (54.49)	64.49 (53.42)	44.21 (41.68)	59.48 (50.46)
6.	Azadirachtin 0.03 EC	5 ml/L	16.14 (23.69)	22.73 (28.47)	18.62 (25.56)	11.49 (19.81)	17.25 (24.54)	17.06 (24.40)	24.03 (29.35)	19.69 (26.34)	12.15 (20.40)	18.23 (25.28)
7.	NSKE	5 ml/L	11.90 (20.18)	17.24 (24.53)	13.55 (21.60)	7.98 (16.41)	12.67 (20.85)	12.58 (20.77)	18.23 (25.28)	14.33 (22.24)	8.44 (16.89)	13.40 (21.47)
8.	*Metarhizum anispopliae* 1.15 WP	5 g/L	22.80 (28.52)	31.32 (34.03)	25.71 (30.47)	16.12 (23.67)	23.99 (29.33)	24.10 (29.40)	33.11 (35.13)	27.18 (31.42)	17.04 (24.38)	25.36 (30.24)
9.	*Lecanicillium lecani* 1.15 WP	5 g/L	24.83 (29.89)	33.28 (35.23)	27.41 (31.57)	18.23 (25.28)	25.94 (30.62)	26.25 (30.82)	35.19 (36.39)	28.98 (32.57)	19.27 (26.04)	27.42 (31.58)
10.	Fipronil 5 SC	0.01%	64.64 (53.51)	70.38 (57.03)	67.10 (55.00)	52.14 (46.23)	63.57 (52.87)	68.33 (55.75)	74.41 (59.61)	70.94 (57.38)	55.12 (47.94)	67.20 (55.06)
11.	Untreated Control	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm±		1.03	0.98	1.25	1.20	1.01	1.25	1.06	1.33	1.22	0.89
	CD at 5%		2.94	2.84	3.64	3.52	2.96	3.62	3.03	3.91	3.50	2.63

PTP = Pre-treatment population, DAS: Days after spray. Figures in parentheses are angular transformed values

Table 6 : Impact of biorational insecticides on spiders during *Kharif*, 2025.

S. No.	Treatments	Conc.	Per cent reduction in spider population days after spray									
			I spray					II Spray				
			1 DAS	3 DAS	7 DAS	10DAS	Mean	1 DAS	3 DAS	7 DAS	10DAS	Mean
1.	Chlorantraniliprole 18.5 SC	0.006%	48.70 (44.26)	53.39 (46.94)	51.42 (45.81)	32.64 (34.84)	46.54 (43.01)	52.24 (46.28)	57.26 (49.17)	55.15 (47.96)	35.01 (36.28)	49.92 (44.95)
2.	Emamectin benzoate 5 SG	0.002%	40.59 (39.58)	46.27 (42.86)	43.29 (41.19)	26.06 (30.70)	39.05 (38.68)	43.54 (41.29)	49.63 (44.79)	46.43 (42.95)	27.95 (31.92)	41.89 (40.33)
3.	Spinosad 45 SC	0.014%	39.84 (39.14)	44.77 (42.00)	42.65 (40.77)	24.89 (29.93)	38.04 (38.08)	42.73 (40.82)	48.02 (43.87)	45.74 (42.56)	26.70 (31.11)	40.80 (39.70)
4.	Flubendiamide 39.35 SC	0.009%	50.68 (45.39)	55.34 (48.07)	52.36 (46.35)	34.31 (35.86)	48.17 (43.95)	54.36 (47.50)	59.36 (50.39)	56.16 (48.54)	36.80 (37.35)	51.67 (45.96)
5.	Spiromsifen 22.9 SC	0.024%	57.06 (49.06)	60.05 (50.80)	58.45 (49.86)	40.07 (39.27)	53.91 (47.24)	61.20 (51.47)	64.41 (53.38)	62.69 (52.35)	42.98 (40.96)	57.82 (49.50)
6.	Azadirachtin 0.03 EC	5 ml/L	15.47 (23.16)	21.78 (27.82)	17.84 (24.98)	11.01 (19.38)	16.53 (23.99)	16.59 (24.04)	23.36 (28.90)	19.14 (25.94)	11.81 (20.10)	17.73 (24.90)
7.	NSKE	5 ml/L	11.40 (19.73)	16.52 (23.98)	12.98 (21.12)	7.65 (16.41)	12.14 (20.39)	12.23 (20.47)	17.72 (24.89)	13.92 (21.91)	8.21 (16.65)	13.02 (21.15)
8.	*Metarhizum anispopliae* 1.15 WP	5 g/L	21.84 (27.86)	30.01 (33.22)	24.63 (29.75)	15.45 (23.15)	22.98 (28.65)	23.43 (28.95)	32.19 (34.57)	26.42 (30.93)	16.57 (24.02)	24.65 (29.77)
9.	*Lecanicillium lecani* 1.15 WP	5 g/L	23.79 (29.19)	31.89 (34.38)	26.26 (30.83)	17.47 (24.71)	24.85 (29.90)	25.52 (30.34)	34.20 (35.79)	28.17 (32.06)	18.74 (25.65)	26.66 (31.09)
10.	Fipronil 5 SC	0.01%	61.94 (51.91)	67.43 (55.20)	64.29 (53.30)	49.96 (44.98)	60.91 (51.30)	66.44 (54.60)	72.33 (58.26)	68.96 (56.14)	53.59 (47.06)	65.33 (53.93)
11.	Untreated Control	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm±		1.00	0.95	1.19	1.16	1.11	1.06	1.02	1.22	1.21	0.96
	CD at 5%		2.78	2.72	3.47	3.39	3.19	3.11	2.96	3.51	3.49	2.83

PTP = Pre-treatment population, DAS: Days after spray. Figures in parentheses are angular transformed values

Table 7 : Impact of biorational insecticides on spider (Pooled data during *Kharif*, 2024 and 2025).

S. No.	Treatments	Conc.	Per cent reduction in spider population days after spray									
			I spray					II Spray				
			1 DAS	3 DAS	7 DAS	10DAS	Mean	1 DAS	3 DAS	7 DAS	10DAS	Mean
1.	Chlorantraniliprole 18.5 SC	0.006%	49.77 (44.87)	54.56 (47.61)	52.54 (46.46)	33.36 (35.28)	47.55 (43.60)	52.99 (46.71)	58.09 (49.65)	55.94 (48.41)	35.52 (36.58)	50.63 (45.36)
2.	Emamectin benzoate 5 SG	0.002%	41.48 (40.09)	47.28 (43.44)	44.24 (41.69)	26.63 (31.07)	39.91 (39.18)	44.17 (41.65)	50.34 (45.19)	47.10 (43.33)	28.36 (32.17)	42.49 (40.68)
3.	Spinosad 45 SC	0.014%	40.72 (39.65)	45.75 (42.56)	43.59 (41.31)	25.44 (30.29)	38.87 (38.57)	43.35 (41.18)	48.71 (44.26)	46.41 (42.94)	27.09 (31.36)	41.39 (40.04)
4.	Flubendiamide 39.35 SC	0.009%	51.79 (46.03)	56.55 (48.76)	53.50 (47.01)	35.07 (36.31)	49.23 (44.56)	55.14 (47.95)	60.22 (50.89)	56.97 (49.00)	37.34 (37.66)	52.41 (46.38)
5.	Spiromsifen 22.9 SC	0.024%	58.31 (49.78)	61.37 (51.57)	59.73 (50.61)	40.95 (39.78)	55.09 (47.92)	62.08 (51.99)	65.34 (53.93)	63.59 (52.89)	43.60 (41.32)	58.65 (49.98)
6.	Azadirachtin 0.03 EC	5 ml/L	15.81 (23.43)	22.26 (28.15)	18.23 (25.28)	11.25 (19.60)	16.89 (24.26)	16.83 (24.22)	23.70 (29.13)	19.42 (26.14)	11.98 (20.25)	17.98 (25.09)
7.	NSKE	5 ml/L	11.65 (19.96)	16.88 (24.26)	13.27 (21.36)	7.82 (16.23)	12.40 (20.62)	12.41 (20.62)	17.98 (25.09)	14.13 (22.08)	8.33 (16.77)	13.21 (21.31)
8.	*Metarhizum anispopliae* 1.15 WP	5 g/L	22.32 (28.19)	30.67 (33.63)	25.17 (30.11)	15.79 (23.41)	23.49 (28.99)	23.77 (29.18)	32.65 (34.85)	26.80 (31.18)	16.81 (24.20)	25.01 (30.00)
9.	*Lecanicillium lecani* 1.15 WP	5 g/L	24.31 (29.54)	32.59 (34.81)	26.84 (31.20)	17.85 (24.99)	25.40 (30.26)	25.89 (30.58)	34.70 (36.09)	28.58 (32.31)	19.01 (25.85)	27.04 (31.33)
10.	Fipronil 5 SC	0.01%	63.29 (52.71)	68.91 (56.11)	65.70 (54.15)	51.05 (45.60)	62.24 (52.08)	67.39 (55.17)	73.37 (58.93)	69.95 (56.76)	54.36 (47.50)	66.27 (54.49)
11.	Untreated Control	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm±		1.21	1.32	1.30	1.15	0.95	1.22	1.36	1.33	1.19	1.03
	CD at 5%		3.44	3.85	3.82	3.29	2.78	3.53	4.02	3.97	3.42	3.05

PTP = Pre-treatment population, DAS: Days after spray. Figures in parentheses are angular transformed values

Declaration

The authors declare no conflict of interest.

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