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Impact of certain granular and foliar insecticides on beneficial fauna in rice ecosystem

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ABSTRACT

This study was conducted to investigate the effect of insecticides with different mode of actions and different toxicity levels against coccinellids and spiders in rice ecosystem at Regional Agricultural Research Station, Warangal during *rabi,* 2020-21 with the test cultivar Telangana Sona (RNR-15048). The selected granular and foliar insecticides *viz.,* flubendiamide 0.7G, flubendiamide 20 WDG, cartap hydrochloride 4G, cartap hydrochloride 50 SP, chlorantraniliprole 0.4G, chlorantraniliprole 18.5 SC, fipronil 0.3G, fipronil 5 SC and carbofuran 3G (check insecticide) were evaluated for their safety against the populations of coccinellids and spiders in rice ecosystem. The insecticides were applied twice, *i.e,* granular formulations were applied either in nursery or 25 DATor both while spray formulations were used at 60 DAT (at panicle initiation to booting stage). Out of 14 treatments, maximum population of beneficials (coccinellids and spiders) were registered in untreated control (T_{14}) followed by carbofuran (T_{13}) with 38.83% reduction, fipronil (T_{10}, T_{11}, T_{12}) and chlorantraniliprole (T_7, T_8 and T_9) ranging from 40.80 to 63.22% reduction whereas flubendiamide (T_1, T_2 and T_3) and cartap hydrochloride (T_4, T_5 and T_6) were found to have greater impact on beneficial fauna (58.78 to 77.78% reduction over control). From the study it was evident that carbofuran, fipronil and chlorantraniliprole were found relatively safer to beneficial populations in rice ecosystem.

Key words : *Beneficials, Insecticides, Rice and toxicity*

Introduction

Rice (*Oryza sativa* L) belongs to the family Poaceae and is the staple food of 65% of the total population in India. It constitutes about 52% of the total food grain production and 55% of total cereal production (Sharanappa *et al.,* 2019). In India, paddy is grown in 43.66 million ha of the total cultivable area. About 70% of our farmers are cultivating paddy and the production is about 118.87 million metric tons and productivity being 2722 kg/ha. The total area under food grains and other important crops in Telangana is 57.72 lakh hectares with rice occupying an area of 23.4 lakh hectares in 2019-20 as against only 14.2 lakh hectares in 2014-15 showing an increasing trend (Pathak *et al.,* 2019). The average productivity of the state during 2014-15 was about 3.10 t/ha which has been estimated to increase by about 0.50

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tonnes (3.60 t/ha) by 2019-20 owing to the large scale adoption of newly released rice varieties.The major constraints of rice production are the high incidence of pests and indiscriminate use of chemical insecticides (Rola and Pingali, 1993) that disrupts the natural balance between insect pests and their natural enemies (Gangurde, 2007). Therefore, assessment of the effects of pesticides that have on the populations of beneficials is an important part of successful IPM program in rice ecosystem. The objective of this study is to evaluate the insecticides safety based on toxicity to insect predators, coccinellids and spiders underfield conditions.

Materials and Methods

The study was carried out at Regional Agricultural Research Station (RARS), Warangal during *rabi*, 2020-21. To study the impact of certain granular and foliar insecticides on coccinellids and spiders population, an experiment was laid out in RBD (randomized block design) with 14 treatments, replicated thrice. The rice variety Telangana Sona (RNR-15048) was used. The nursery was sown on 28th November, 2020 with 18 nursery beds and each bed with 2.4 sq.m. area (1.6 m × 1.5 m). Each bed was well separated by providing bunds to prevent the movement of water and insecticide from one bed to another. Granular insecticides were applied in nursery, one week before nursery pulling as per protocol (Table 1) and their impact on beneficials were assessed at 25 DAT.

The main field experiment was carried out with 14 treatments and 3 replications in randomized block design. Granular and spray formulations of flubendiamide, cartap hydrochloride, chlorantranilirpole and fipronil were tested in order to test impact on population of coccinellids and spiders at different combinations *viz.,* nursery and 25 DAT (days after transplanting), 25 DAT and panicle initiation to booting and nursery, 25 DAT and Panicle initiation to booting along with carbofuran as insecticide check. One month old seedlings were transplanted at a spacing of 20 x 15 cm in plots with gross plot size 26.4 sq.m. Each plot was separated by providing bunds and irrigation channels and care was taken to prevent movement of insecticide or water from one field to another. All the standard and recommended agronomic practices were followed uniformly in all the plots. Observations on the incidence of coccinellids and spiders population were recorded from 25 DAT and was calculated by visual counting number per hill from each plot, from ten randomly selected plants at 10 days interval before and after imposing treatment. Data recorded in the different treatments were subjected to statistical analysis after suitable transformation (square root transformation) by following standard procedures of RBD experiment (Gomez and Gomez, 1984).

Results and Discussion

Impact of insecticidal treatments on coccinellids population

The coccinellids populations were low during *rabi*, 2020-2021 in all the treatments. However, they appeared from early tillering to grain filling stage of the crop (Table 2 and 3). Coccinellid populations during vegetative stage ranged from 0.00 to 0.23/ hill at 25 DAT. No population was noticed in the treatments of flubendiamide 0.7G @ 625 g/ha (T_3) and cartap hydrochloride 4G @ 1000 g/ha (T_4 and T_6). Carbofuran 3G @ 2000 g/ha (T_{13}) with 0.10/hill that remained at par with chlorantraniliprole 0.4G @ 500 g/ha treated plots (T_7 and T_9 each with 0.03/hill population). However, highest mean population was observed in untreated control plot (T_{14} with 0.23/hill).

Perusal of data at 25 DAT(Table 3) revealed that the per cent reduction of coccinellids ranged from 56.52 to 100% over control in the insecticide treatments. Flubendiamide 0.7G @ 625 g/ha (T_3) and cartap hydrochloride 4G @ 1000 g/ha (T_4 and T_6) reported 100 per cent population reduction over control while, carbofuran 3G @ 2000 g/ha (T_{13}) registered 56.52 per cent reduction followed by chlorantraniliprole 0.4G @ 500 g/ha treatments (T_7 and T_9).

At 35 DAT, population ranged from 0.00 to 0.33/ hill with lowest population observed in flubendiamide 0.7G @ 12.5 kg/ha (T_3 and T_2) and cartap hydrochloride 4G @ 20 kg/ha (T_6). Fipronil 0.3G @ 1000 g/ha (T_{10}) and carbofuran 3G @ 2000 g/ ha (T_{13}) reported highest population (0.23 and 0.13/ hill) next to untreated control (0.33/hill). This was followed by chlorantraniliprole 0.4G @ 500 g/ha (T_7 and T_8) with 0.17 and 0.10/hill, respectively.

Perusal of data at 35 DAT revealed that 100 per cent population reduction over control was noticed in flubendiamide 0.7G @ 12.5 kg/ha (T_2 and T_3) and cartap hydrochloride 4G @ 20 kg/ha. Population reduction of coccinellids was lowest in fipronil 0.3G @ 1000 g/ha (T10) and carbofuran 3G @ 25 kg/ha

Table 1. Schedule of various insecticidal treatments

S. No.	Insecticides	Treatments	Formulation	Dosage/ha		Time of application
				a.i./ ha	Formulation in g/ml/ ha	
01	Flubendiamide	T_1	0.7 G	87.5 g. a.i./ha	625 g/ ha (500 m^2 area)	Nursery stage
			20 WDG	25 g. a.i./ha	125 g/ ha	P.I. to Booting stage
		T_2	0.7 G	87.5 g. a.i./ha	12.5 kg/ ha	25 DAT
			20 WDG	25 g. a.i./ha	125 g/ ha	P.I. to Booting stage
		T_3	0.7 G	87.5 g. a.i./ha	625 g/ ha (500 m^2 area)	Nursery stage
					12.5 kg/ ha	25 DAT
			20 WDG	25 g. a.i./ha	125 g/ ha	P.I. to Booting stage
02	Cartap hydrochloride	T_4	4 G	800 g. a.i./ ha	1000 g/ ha (500 m^2 area)	Nursery stage
			50 SP	500 g. a.i./ha	1000 g/ ha	P.I. to Booting stage
		T_5	4 G	800 g. a.i./ ha	20 kg/ ha	25 DAT
			50 SP	500 g. a.i./ha	1000 g/ ha	P.I. to Booting stage
		T_6	4 G	800 g. a.i./ ha	1000 g/ ha (500 m^2 area)	Nursery stage
					20 kg/ ha	25 DAT
			50 SP	500 g. a.i./ha	1000 g/ ha	P.I. to Booting stage
03	Chlorantraniliprole	T_7	0.4 G	40 g. a.i./ ha	500 g/ ha (500 m^2 area)	Nursery stage
			18.5 SC	30 ml. a.i./ ha	150 ml/ ha	P.I. to Booting stage
		T_8	0.4 G	40 g. a.i./ ha	10 kg/ ha	25 DAT
			18.5 SC	30 ml. a.i./ ha	150 ml/ ha	P.I. to Booting stage
		T_9	0.4 G	40 g. a.i./ ha	500 g/ ha (500 m^2 area)	Nursery stage
					10 kg/ ha	25 DAT
			18.5 SC	30 ml. a.i./ ha	150 ml/ ha	P.I. to Booting stage
04	Fipronil	T_{10}	0.3 G	60 g. a.i./ ha	1000 g/ ha (500 m^2 area)	Nursery stage
			5 SC	50 ml. a.i./ ha	1000 ml/ ha	P.I. to Booting stage
		T_{11}	0.3 G	60 g. a.i./ ha	20 kg/ ha	25 DAT
			5 SC	50 ml. a.i./ ha	1000 ml/ ha	P.I. to Booting stage
		T_{12}	0.3 G	60 g. a.i./ ha	1000 g/ ha (500 m^2 area)	Nursery stage
					20 kg/ ha	25 DAT
			5 SC	50 ml. a.i./ ha	1000 ml/ ha	P.I. to Booting stage
05	Carbofuran (check)	T_{13}	3 G	750 g. a.i./ ha	2000 g/ ha (500 m^2 area)	Nursery stage
					25 kg/ ha	25 DAT
06	Untreated Control	T_{14}	-	-	-	-

*P.I. = Panicle initiation, a.i. = active ingredient
Note: Nursery recommendation of Carbofuran is 800 g/ 200 m^2

treatment with 30.30 and 60.61% over control, respectively.

At 45 DAT, the population ranged from 0.17 to 1.27/hill with highest being recorded in untreated control (1.27/hill) and lowest in cartap hydrochloride 4G @ 20 kg/ha (T_6) with 0.17/hill. Next safer treatments were carbofuran 3G @ 25 kg/ha (T_{13}) with 0.77/hill, chlorantraniliprole 0.4G @ 500 g/ha (T_7) with 0.70/hill and fipronil 0.3G @ 1000 g/ha (T_{10}) with 0.63/hill. Lowest population of coccinellids were registered in cartap hydrochloride 4G @ 20 kg/ha and flubendiamide 0.7G @ 12.5 kg/ha treatments ranging from 0.23 to 0.40/hill.

It can be deduced from perusal of data at 45 DAT that the treatments carbofuran 3G @ 25 kg/ha (T_{13}), chlorantraniliprole 0.4G @ 500g/ha (T_7) and fipronil 0.3G @ 1000 g/ha (T_{10}) registered lowest per cent reduction of population over control with 39.37, 44.88 and 50.39% respectively. Highest per cent reduction was noticed in cartap hydrochloride 4G @ 20 kg/ha treatments (T_6 and T_5) with 86.61 and 81.89% followed by flubendiamide 0.7G @ 12.5 kg/ha (T_3) with 81.89% reduction.

At 55 DAT, population of coccinellids ranged from 0.53 to 1.57/hill. Highest population was noticed in untreated control (T_{14} with 1.70/hill) followed by fipronil 0.3G @ 1000 g/ha (T_{10}) with 1.07/hill, chlorantraniliprole 0.4G @ 500 g/ha (T_7) and flubendiamide 0.7G @ 625 g/ha (T_1) with 1.03/hill each, carbofuran 3G @ 25 kg/ha (T_{13}) with 0.87/hill and fipronil 0.3G @ 20 kg/ha (T_{11}) with 0.83/hill. Highest per cent reduction of population was noticed in cartap hydrochloride 4G @ 20 kg/ha (T_6) with 66.24%, flubendiamide 0.7G @ 12.5 kg/ha (T_3) with 61.78% while lowest per cent reduction was noticed in fipronil 0.3G @ 1000 g/ha (T_{10} and T_{11}) with 31.85 and 47.13% respectively and chlorantraniliprole 0.4G @ 10 kg/ha (T_8) with 49.04%.

At 60 DAT, population ranged from 0.80 to 1.63/hill with lowest population being recorded in cartap hydrochloride 4G @ 20 kg/ha (T_5) with 0.77/hill followed by flubendiamide 0.7G @ 12.5 kg/ha (T_3 and T_2) with 0.83 and 0.87/hill. Highest population was recorded in untreated control (1.63/hill) followed by fipronil 0.3G @ 1000 g/ha (T_{10}) and carbofuran 3G @ 25kg/ha (T_{13}) with 1.40/hill and 1.33/hill, respectively.

From the perusal of data (Table 3), highest reduction of population occurred in cartap hydrochloride 4G @ 20 kg/ha (T_5 and T_6) with 52.76 and 50.92% followed by flubendiamide 0.7G @ 12.5 kg/ha treatments (T_3 and T_2) with 49.08 and 46.62%, respectively.

At 65 DAT, population ranged from 0.63 to 1.70/hill, highest population was observed in untreated control (1.70/hill) followed by carbofuran 3G @ 25 kg/ha (T_{13}) with 1.47/hill, fipronil 0.3G @ 20 kg/ha + 5 SC @ 1000 ml/ha (T_{10} and T_{11}) with 1.17 and 1.13/hill and chlorantraniliprole 0.7G @ 500 g/ha + 18.5 SC @ 150 ml/ha (T_7) with 1.10/hill.

The overall mean population of coccinellids ranged from 0.36 to 1.12/hill between the treatments (Table 2 and 3). Highest population was noticed in untreated control (T_{14}) with 1.12/hill followed by carbofuran 3G @ 2000 g/ha + 25 kg/ha (T13) with 0.77%, fipronil 0.3G @ 1000 g/ha + 5 SC @ 1000 ml/ha (T_{10}) with 0.76/hill, chlorantaniliprole 0.4G @ 500 g/ha + 10 kg/ha (T_7) with 0.73/hill while lowest was registered in cartap hydrochloride 4G @ 125 g/ha + 20 kg/ha + 50 SP @ 1000 g/ha (T_6) with 0.36/hill followed by flubendiamide 0.7G @ 625 g/ha + 12.5 kg/ha + 20 WDG @ 125 g/ha (T_3) with 0.41/hill. From the perusal of data (Table 3), it was clear that highest reduction of population was noticed in cartap hydrochloride 4G @ 125 g/ha + 20 kg/ha + 50 SP @ 1000 g/ha (T_6) with 77.78% followed by flubendiamide 0.7G @ 625 g/ha + 12.5 kg/ha + 20 WDG @ 125 g/ha (T_3) with 74.28% while lowest reduction was noticed in carbofuran 3G @ 2000 g/ha + 25 kg/ha (T_{13}) with 38.83% and fipronil 0.3G @ 1000 g/ha + 5 SC @ 1000 ml/ha (T_{10}) with 40.80 % reduction over control.

Higher population of coccinellids (1.57/hill) in carbofuran 3G treated plots was noticed, followed by fipronil (T_{10}) and chlorantraniliprole (T_7). These chemicals due to their lower toxicity level supported good population of coccinellids. These findings were in accordance with the results of Rahaman and Stout (2019); Srinivas and Madhumathi (2005); Mange and Sachan (2013) while minimum population was registered in plots treated with cartap hydrochloride (T_5 with 0.80/hill and T_6 with 0.83/hill) as that of Jafar *et al.* (2013). Both flubendiamide and cartap hydrochloride treatments proved to be more toxic to coccinellids compared with other treatments, while carbofuran, fipronil and chlorantraniliprole were relatively safe to coccinellids.

Impact of insecticidal treatments on spiders population

The predatory spiders appeared from early phase to grain filling stage of the crop and the results are presented from Table 4 and 5. Spider population during vegetative stage *i.e.* at 25 DAT ranged from 0.06 to 0.50/hill. Lowest population was noticed in the treatments of cartap hydrochloride 4G @ 1000 g/ha (T_6 and T_4), flubendiamide 0.7G @ 625 g/ha (T_1) with 0.06, 0.10 and 0.17/hill, respectively while, highest population was registered in untreated control (T_{14}) with 0.50/hill followed by carbofuran 3G @ 2000 g/ha (T_{13}) and fipronil 0.3G @ 1000 g/ha (T_{11}) with 0.37/hill in each treatment. Next best treatments were fipronil 0.3G @ 1000 g/ha (T_{12} and T_{10}) with 0.30/hill each and chlorantraniliprole 0.4G @ 500 g/ha (T_7 and T_8) with 0.27/hill each. However, no significant variation was noticed between the treatments.

But, perusal of data (Table 5) at 25 DAT revealed that the per cent reduction of spiders ranged from 26.00 to 88.00% over control. Cartap hydrochloride 4G @ 1000 g/ha (T_6 and T_4) and flubendiamide 0.7G @ 625 g/ha (T_1) reported highest per cent reduction ranging from 88.00 to 66.00% while carbofuran 3G @ 2000 g/ha (T_{13}) registered lowest (26.00%) per cent reduction followed by fipronil 0.3G @ 1000 g/ha (T_{11} and T_{12}) with 26.00 and 40.00 per cent and chlorantraniliprole 0.4G @ 500 g/ha treatments (T_7 and T_8) with 46 per cent reduction each.

At 35 DAT, population ranged from 0.07 to 0.80/hill with lowest population noticed in cartap hydro-

Table 2. Impact of granular and spray formulations of insecticides on coccinellid population during *rabi*, 2020-21

Insecticide	Tr. No.	Time of application $	Formulation	Formulation dosage g/ml per ha	Population of Coccinellids (Number/hill) 25 DAT (25/01/21)	35 DAT (04/02/21)	45 DAT (14/02/21)	55 DAT (24/02/21)	60 DAT (01/03/21)	65 DAT (06/03/21)	Overall % Mean of population
Flubendiamide	T_1	N	0.7 G	625 g/ ha	0.03^{bc}	0.03^{c}	0.40^{b}	1.03^{bc}	1.10^{c}	1.03^{b}	0.61^{c}
		PI to B	20 WDG	125 g/ ha	(1.02)	(1.02)	(1.18)	(1.43)	(1.45)	(1.42)	(1.27)
	T_2	25 DAT	0.7 G	12.5 kg/ ha	0.07^{bc}	0.00^{c}	0.30^{b}	0.77^{cd}	0.87^{d}	0.80^{b}	0.48^{d}
		PI to B	20 WDG	125 g/ ha	(1.03)	(1.00)	(1.14)	(1.33)	(1.37)	(1.34)	(1.21)
	T_3	N + 25 DAT	0.7 G	625 g/ha + 12.5 kg/ ha	0.00	0.00^{c}	0.23^{b}	0.60^{d}	0.83^{d}	0.80^{b}	0.41^{d}
		PI to B	20 WDG	125 g/ ha	^{c}(1.00)	(1.00)	(1.11)	(1.26)	(1.35)	(1.34)	(1.19)
Cartap hydrochloride	T_4	N	4 G	1000 g/ ha	0.00^{c}	0.03^{c}	0.27^{b}	0.97^{bc}	1.10^{c}	0.87^{b}	0.54^{cd}
		PI to B	50 SP	1000 g/ ha	(1.00)	(1.02)	(1.12)	(1.40)	(1.45)	(1.36)	(1.24)
	T_5	25 DAT	4 G	20 kg/ ha	0.07^{bc}	0.03^{c}	0.23^{b}	0.70^{cd}	0.77^{d}	0.67^{b}	0.41^{d}
		PI to B	50 SP	1000 g/ ha	(1.03)	(1.02)	(1.11)	(1.30)	(1.33)	(1.29)	(1.19)
	T_6	N + 25 DAT	4 G	1000 g/ ha + 20 kg/ ha	0.00^{c}	0.00^{c}	0.17^{a}	0.53^{d}	0.80^{d}	0.63^{b}	0.36^{d}
		PI to B	50 SP	1000 g/ ha	(1.00)	(1.00)	(1.08)	(1.24)	(1.34)	(1.28)	(1.16)
Chlorantraniliprole	T_7	N	0.4 G	500 g/ ha	0.03^{bc}	0.17^{b}	0.70^{ab}	1.03^{bc}	1.23^{bc}	1.10^{ab}	0.73^{bc}
		PI to B	18.5 SC	150 ml/ ha	(1.02)	(1.08)	(1.30)	(1.43)	(1.49)	(1.45)	
(1.32)											
	T_8	25 DAT	0.4 G	10 kg/ ha	0.07^{bc}	0.10^{bc}	0.43^{b}	0.80^{c}	1.17^{bc}	1.00^{b}	0.59^{cd}
		PI to B	18.5 SC	150 ml/ ha	(1.03)	(1.05)	(1.19)	(1.34)	(1.47)	(1.41)	(1.26)
	T_9	N + 25 DAT	0.4 G	500 g/ ha + 10 kg/ ha	0.03^{bc}	0.07^{bc}	0.27^{b}	0.73^{cd}	1.10^{c}	0.87^{b}	0.51^{cd}
		PI to B	18.5 SC	150 ml/ ha	(1.02)	(1.03)	(1.12)	(1.32)	(1.45)	(1.36)	(1.23)
Fipronil	T_{10}	N	0.3 G	1000 g/ ha	0.03^{bc}	0.23^{ab}	0.63^{b}	1.07^{b}	1.40^{a}	1.17^{ab}	0.76^{bc}
		PI to B	5 SC	1000 ml/ ha	(1.02)	(1.11)	(1.28)	(1.44)	(1.55)	(1.46)	(1.32)
	T_{11}	25 DAT	0.3 G	20 kg/ ha	0.00^{c}	0.07^{bc}	0.53^{b}	0.83^{c}	1.30^{bc}	1.13^{ab}	0.64^{bc}
		PI to B	5 SC	1000 ml/ ha	(1.00)	(1.03)	(1.23)	(1.35)	(1.52)	(1.46)	(1.28)
	T_{12}	N + 25 DAT	0.3 G	1000 g/ ha + 20 kg/ ha	0.07^{bc}	0.10^{bc}	0.33^{b}	0.73^{cd}	1.13^{bc}	1.03^{b}	0.57^{cd}
		PI to B	5 SC	1000 ml/ ha	(1.03)	(1.05)	(1.15)	(1.31)	(1.46)	(1.42)	(1.25)
Carbofuran	T_{13}	N	3 G	2000 g/ ha	0.10^{b}	0.13^{bc}	0.77^{ab}	0.87^{c}	1.33^{b}	1.47^{ab}	0.77^{b}
		25 DAT	3 G	25 kg/ ha	(1.05)	(1.06)	(1.32)	(1.36)	(1.53)	(1.56)	(1.33)
Untreated control (Water spray)	T_{14}	-	-	-	0.23^{a} (1.11)	0.33^{a} (1.15)	1.27^{a} (1.50)	1.57^{a} (1.60)	1.63^{a} (1.62)	1.70^{a} (1.64)	1.12^{a} (1.46)
SE(m) ±	0.01	0.02	0.07	0.02	0.02	0.07	0.02				
$C.D_{(0.05)}$	0.04	0.05	0.20	0.07	0.07	0.20	0.05				
C.V.	2.51	3.03	10.09	2.86	2.85	8.24	2.41				

*Figures in the parenthesis are (x + 1.0) transformed values; $ = Insecticides applied in N: Nursery, at 25 DAT, PI to B : at Panicle initiation to Booting stage

Table 3. Per cent reduction of coccinellid population over control during *rabi*, 2020-21

Insecticide	Tr. No.	Time of application $	Formulation	Formulation dosage g/ml per ha	% reduction of coccinellid population over control						Overall % Mean of population reduction over control
					25 DAT (25/01/21)	35 DAT (04/02/21)	45 DAT (14/02/21)	55 DAT (24/02/21)	60 DAT (01/03/21)	65 DAT (06/03/21)	
Flubendiamide	T_1	N PI to B	0.7 G 20 WDG	625 g/ ha 125 g/ ha	86.96	90.91	68.50	34.39	32.51	39.41	58.78
	T_2	25 DAT PI to B	0.7 G 20 WDG	12.5 kg/ ha 125 g/ ha	69.56	100.00	76.38	50.95	46.62	52.94	66.07
	T_3	N + 25 DAT PI to B	0.7 G 20 WDG	625 g/ ha + 12.5 kg/ ha 125 g/ ha	100.00	100.00	81.89	61.78	49.08	52.94	74.28
Cartap hydrochloride	T_4	N PI to B	4 G 50 SP	1000 g/ ha 1000 g/ ha	100.00	90.91	78.74	38.22	32.51	48.82	64.87
	T_5	25 DAT PI to B	4 G 50 SP	20 kg/ ha 1000 g/ ha	69.56	90.91	81.89	55.41	52.76	60.59	68.52
	T_6	N + 25 DAT PI to B	4 G 50 SP	1000 g/ha + 20 kg/ha 1000 g/ ha	100.00	100.00	86.61	66.24	50.92	62.94	77.78
Chlorantraniliprole	T_7	N PI to B	0.4 G 18.5 SC	500 g/ ha 150 ml/ ha	86.96	48.48	44.88	34.39	24.54	35.29	45.76
	T_8	25 DAT PI to B	0.4 G 18.5 SC	10 kg/ ha 150 ml/ ha	69.56	69.70	66.14	49.04	28.22	41.18	53.97
	T_9	N + 25 DAT PI to B	0.4 G 18.5 SC	500 g/ ha + 10 kg/ ha 150 ml/ ha	86.96	78.79	78.74	53.50	32.51	48.82	63.22
Fipronil	T_{10}	N PI to B	0.3 G 5 SC	1000 g/ ha 1000 ml/ ha	86.96	30.30	50.39	31.85	14.11	31.18	40.80
	T_{11}	25 DAT PI to B	0.3 G 5 SC	20 kg/ ha 1000 ml/ ha	100.00	78.79	58.27	47.13	20.24	33.53	56.33
	T_{12}	N + 25 DAT PI to B	0.3 G 5 SC	1000 g/ ha + 20 kg/ ha 1000 ml/ ha	69.56	69.70	74.01	53.50	30.67	39.41	56.14
Carbofuran	T_{13}	N 25 DAT	3 G 3 G	2000 g/ ha 25 kg/ ha	56.52	60.61	39.37	44.58	18.40	13.53	38.83
Untreated control (Water spray)	T_{14}	-	-	-	-	-	-	-	-	-	-

*$ = Insecticides applied in N: Nursery, at 25 DAT, PI to B : at Panicle initiation to Booting stage

chloride 4G @ 20 kg/ha (T_6 and T_5) with 0.07 and 0.16/hill population followed by flubendiamide 0.7G @ 12.5 kg/ha (T_3) with 0.17/hill while, highest population was recorded in untreated control (0.80/hill) followed by carbofuran 3G @ 25 kg/ha (T_{13}), fipronil 0.3G @ 20 kg/ha (T_{10} and T_{11}) and chlorantraniliprole 0.4G @ 500 g/ha (T_7) and flubendiamide 0.7G @ 625 g/ha (T_1) with 0.33/hill population each.

Perusal of data at 35 DAT (Table 5) revealed that highest per cent population reduction over control was registered in cartap hydrochloride 4G @ 20 kg/ha (T_6 and T_5) with 91.25 and 80.00% respectively, followed by flubendiamide 0.7G @ 12.5 kg/ha (T_3 and T_2) with 78.75 and 75.00%, respectively, while lowest per cent reduction was found in carbofuran 3G @ 25 kg/ha (T_{13}), fipronil 0.3G @ 20 kg/ha (T_{10} and T_{11}) and chlorantraniliprole 0.4G @ 500 g/ha (T_7) and flubendiamide 0.7G @ 625 g/ha (T_1) with 58.75% each.

At 45 DAT, the population ranged from 0.37 to 1.53/hill with highest being recorded in untreated control (1.53/hill) and lowest in cartap hydrochloride 4G @ 20 kg/ha (T_6) with 0.37/hill. Next safer treatments were carbofuran 3G @ 25 kg/ha (T_{13}) with 1.40/hill, fipronil 0.3G @ 1000 g/ha (T_{10}) with 0.63/hill, chlorantraniliprole 0.4G @ 500 g/ha (T_7) with 1.10/hill, fipronil 0.3G @ 20 kg/ha (T_{11}) with 0.93/hill, chlorantraniliprole 0.4G @ 10kg/ha (T_8) with 0.90/hill.

It is evident from perusal of data at 45 DAT (Table 5) that the treatments carbofuran 3G @ 25 kg/ha (T_{13}), fipronil 0.3G @ 1000 g/ha (T_{10}), chlorantraniliprole 0.4G @ 500 g/ha (T_7), fipronil 0.3G @ 20 kg/ha (T_{11}), chlorantraniliprole 0.4G @ 10 kg/ha (T_8) resulted in lowest reduction of population of 8.50, 23.53, 28.10, 39.21 and 41.18%, respectively while, highest per cent reduction was registered in cartap hydrochloride 4G @ 20 kg/ha treatments (T_6 and T_5) with 75.82 and 69.28% respectively.

At 55 DAT, population of spiders ranged from 0.70 to 1.63/hill. Highest population was noticed in untreated control (T_{14} with 1.63/hill) followed by carbofuran 3G @ 25 kg/ha (T_{13}) with 1.33/hill, fipronil 0.3G @ 1000 g/ha (T_{10}) with 1.27/hill, chlorantraniliprole 0.4G @ 500 g/ha (T_7) with 1.23/hill while, lowest population was noticed in cartap hydrochloride 4G @ 20 kg/ha (T_6 and T_5) with 0.70 and 0.87/hill followed by flubendiamide 0.7G @ 12.5kg/ha (T_3) with 0.90/hill. However, the treatment differences were non-significant.

But, the data at 55 DAT (Table 5) showed that the treatments carbofuran 3G @ 25 kg/ha (T_{13}), fipronil 0.3G @ 1000 g/ha (T_{10}) and chlorantraniliprole 0.4G @ 500 g/ha (T_7) had lowest reduction of population(18.40, 22.08, 28.10 and 24.54%, respectively) while, highest per cent reduction was registered in cartap hydrochloride 4G @ 20 kg/ha treatments (T_6 and T_5) with 57.05 and 46.62%, respectively.

At 60 DAT, population ranged from 1.00 to 1.97/hill with lowest population being recorded in cartap hydrochloride 4G @ 20 kg/ha treatments (T_6 and T_5) with 1.00 and 1.06/hill respectively, followed by flubendiamide 0.7G @ 12.5 kg/ha (T_3) with 1.10/hill. Highest population was recorded in untreated control (1.97/hill) followed by carbofuran 3G @ 25 kg/ha (T_{13}) with 1.77/hill, fipronil 0.3G @ 1000 g/ha (T_{10}) and chlorantraniliprole 0.4G @ 500 g/ha (T_7) with 1.53/hill each. Highest population reduction over control was noticed in cartap hydrochloride 4G @ 20 kg/ha treatments (T_6 and T_5) with 49.24 and 46.19%, respectively, followed by flubendiamide 0.7G @ 12.5 kg/ha (T_3) with 44.16% while lowest per cent population reduction was registered in carbofuran 3G @ 25 kg/ha (T_{13}) with 10.15%, fipronil 0.3G @ 1000 g/ha (T_{10}) and chlorantraniliprole 0.4G @ 500 g/ha (T_7) with 22.33% each. However, variation between the treatments at this interval remained non-significant.

At 65 DAT, population ranged from 0.90 to 2.20/hill, highest being recorded in untreated control (2.20/hill) followed by carbofuran 3G @ 25 kg/ha (T_{13}) with 1.80/hill, fipronil 0.3G @ 1000g/ha + 5 SC @ 1000 ml/ha (T_{10}) with 1.53/hill and chlorantraniliprole 0.7G @ 500 g/ha + 18.5 SC @ 150 ml/ha (T_7) with 1.47/hill. From the perusal of data (Table 5), it was clear that lowest per cent reduction of population was noticed in carbofuran 3G @ 25 kg/ha (T_{13}) with 18.18% followed by fipronil 0.3G @ 1000 g/ha + 5 SC @ 1000 ml/ha (T_{10}) with 30.45% while highest per cent reduction was noticed in cartap hydrochloride 4G @ 1000 g/ha + 20 kg/ha + 50 SP @ 1000 g/ha (T_6) with 59.09% reduction over control.

The data on overall mean population ranged from 0.52 to 1.32/hill between the treatments (Table 4 and 5). Highest population was noticed in untreated control (T_{14}) with 1.32/hill followed by carbofuran 3G @ 2000 g/ha + 25 kg/ha (T_{13}) with 1.20/hill, fipronil 0.3G @ 1000 g/ha + 5 SC @ 1000 ml/ha (T_{10}) with 1.03/hill, chlorantaniliprole 0.4G @

Table 4.11. Impact of granular and spray formulations of insecticides on spider population during *rabi*, 2020-21

Insecticide	Tr. No.	Time of application $	Formulation	Formulation dosage g/ml per ha	Population of Spiders (Number/hill) 25 DAT (25/01/21)	35 DAT (04/02/21)	45 DAT (14/02/21)	55 DAT (24/02/21)	60 DAT (01/03/21)	65 DAT (06/03/21)	Overall % Mean of population
Flubendiamide	T_1	N	0.7 G	625 g/ ha	0.17	0.33^{b}	1.03^{b}	1.06	1.33	1.30^{bc}	0.88^{bc}
		PI to B	20 WDG	125 g/ ha	(1.08)	(1.16)	(1.42)	(1.45)	(1.53)	(1.51)	(1.37)
	T_2	25 DAT	0.7 G	12.5 kg/ ha	0.30	0.20^{bc}	0.80^{bc}	1.00	1.20	1.13^{bc}	0.77^{cd}
		PI to B	20 WDG	125 g/ ha	(1.14)	(1.09)	(1.34)	(1.41)	(1.48)	(1.46)	(1.33)
	T_3	N + 25 DAT	0.7 G	625 g/ ha + 12.5 kg/ ha	0.23	0.17^{bc}	0.70^{c}	0.90	1.10	1.03^{bc}	0.69^{cd}
		PI to B	20 WDG	125 g/ ha	(1.11)	(1.08)	(1.30)	(1.37)	(1.45)	(1.42)	(1.30)
Cartap hydrochloride	T_4	N	4 G	1000 g/ ha	0.10	0.30^{bc}	0.73^{bc}	1.07	1.23	1.20^{bc}	0.77^{cd}
		PI to B	50 SP	1000 g/ ha	(1.05)	(1.14)	(1.32)	(1.43)	(1.49)	(1.48)	(1.33)
	T_5	25 DAT	4 G	20 kg/ ha	0.20	0.16^{bc}	0.47^{cd}	0.87	1.06	1.00^{bc}	0.63^{d}
		PI to B	50 SP	1000 g/ ha	(1.09)	(1.08)	(1.21)	(1.36)	(1.44)	(1.41)	(1.27)
	T_6	N + 25 DAT	4 G	1000 g/ ha + 20 kg/ ha	0.06	0.07^{c}	0.37^{d}	0.70	1.00	0.90^{c}	0.52^{d}
		PI to B	50 SP	1000 g/ ha	(1.03)	(1.03)	(1.17)	(1.30)	(1.41)	(1.37)	(1.23)
Chlorantraniliprole	T_7	N	0.4 G	500 g/ ha	0.27	0.33^{b}	1.10^{ab}	1.23	1.53	1.47^{b}	0.99^{bc}
		PI to B	18.5 SC	150 ml/ ha	(1.12)	(1.15)	(1.45)	(1.49)	(1.59)	(1.57)	(1.41)
	T_8	25 DAT	0.4 G	10 kg/ ha	0.27	0.23^{bc}	0.90^{bc}	1.13	1.40	1.27^{bc}	0.87^{bc}
		PI to B	18.5 SC	150 ml/ ha	(1.12)	(1.11)	(1.38)	(1.46)	(1.55)	(1.50)	(1.37)
	T_9	N + 25 DAT	0.4 G	500 g/ ha + 10 kg/ ha	0.23	0.30^{bc}	0.67^{c}	1.10	1.30	1.27^{bc}	0.81^{c}
		PI to B	18.5 SC	150 ml/ ha	(1.11)	(1.14)	(1.29)	(1.45)	(1.51)	(1.50)	(1.35)
Fipronil	T_{10}	N	0.3 G	1000 g/ ha	0.30	0.33^{b}	1.17^{ab}	1.27	1.53	1.53^{b}	1.03^{b}
		PI to B	5 SC	1000 ml/ ha	(1.15)	(1.15)	(1.47)	(1.50)	(1.59)	(1.59)	(1.42)
	T_{11}	25 DAT	0.3 G	20 kg/ ha	0.37	0.33^{b}	0.93^{bc}	1.17	1.50	1.47^{b}	0.96^{bc}
		PI to B	5 SC	1000 ml/ ha	(1.17)	(1.15)	(1.39)	(1.47)	(1.58)	(1.57)	(1.40)
	T_{12}	N + 25 DAT	0.3 G	1000 g/ ha + 20 kg/ ha	0.30	0.30^{bc}	0.77^{bc}	1.13	1.43	1.40^{bc}	0.89^{bc}
		PI to B	5 SC	1000 ml/ ha	(1.15)	(1.14)	(1.33)	(1.46)	(1.56)	(1.55)	(1.38)
Carbofuran	T_{13}	N	3 G	2000 g/ ha	0.37	0.33^{ab}	1.40^{a}	1.33	1.77	1.80^{ab}	1.20^{ab}
		25 DAT	3 G	25 kg/ ha	(1.17)	(1.23)	(1.55)	(1.52)	(1.66)	(1.67)	(1.48)
Untreated control	T_{14}	-	-	-	0.50	0.80^{a}	1.53^{bc}	1.63	1.97	2.20^{a}	1.32^{a}
(Water spray)					(1.22)	(1.34)	(1.34)	(1.62)	(1.72)	(1.79)	(1.52)
SE(m) ±	0.03	0.04	0.04	0.07	0.06	0.06	0.02				
$C.D_{(0.05)}$	NS	0.11	0.11	NS	NS	0.19	0.06				
C.V.	5.40	5.72	4.98	8.88	7.18	7.36	2.59				

$ = Insecticides applied in N: Nursery, at 25 DAT, PI to B : at Panicle initiation to Booting stage

Table 4.12. Per cent decrease of spider population over control during *rabi*, 2020-21

Insecticide	Tr. No.	Time of application $	Formulation	Formulation dosage g/ml per ha	Per cent reduction of Spiders population over control						Overall % Mean of population reduction over control
					25 DAT (25/01/21)	35 DAT (04/02/21)	45 DAT (14/02/21)	55 DAT (24/02/21)	60 DAT (01/03/21)	65 DAT (06/03/21)	
Flubendiamide	T_1	N PI to B	0.7 G 20 WDG	625 g/ ha 125 g/ ha	66.00	58.75	32.68	34.97	32.49	40.91	44.3
	T_2	25 DAT PI to B	0.7 G 20 WDG	12.5 kg/ ha 125 g/ ha	40.00	75.00	47.71	38.65	39.09	48.64	48.18
	T_3	N + 25 DAT PI to B	0.7 G 20 WDG	625 g/ ha + 12.5 kg/ ha 125 g/ ha	54.00	78.75	54.25	44.78	44.16	53.18	54.85
Cartap hydrochloride	T_4	N PI to B	4 G 50 SP	1000 g/ ha 1000 g/ ha	80.00	62.5	52.29	34.35	37.56	45.45	52.02
	T_5	25 DAT PI to B	4 G 50 SP	20 kg/ ha 1000 g/ ha	60.00	80.00	69.28	46.62	46.19	54.54	59.44
	T_6	N + 25 DAT PI to B	4 G 50 SP	1000 g/ ha + 20 kg/ ha 1000 g/ ha	88.00	91.25	75.82	57.05	49.24	59.09	70.07
Chlorantraniliprole	T_7	N PI to B	0.4 G 18.5 SC	500 g/ ha 150 ml/ ha	46.00	58.75	28.10	24.54	22.33	33.18	35.48
	T_8	25 DAT PI to B	0.4 G 18.5 SC	10 kg/ ha 150 ml/ ha	46.00	71.25	41.18	30.67	28.93	42.27	43.38
	T_9	N + 25 DAT PI to B	0.4 G 18.5 SC	500 g/ ha + 10 kg/ ha 150 ml/ ha	54.00	62.50	56.21	32.51	34.01	42.27	46.92
Fipronil	T_{10}	N PI to B	0.3 G 5 SC	1000 g/ ha 1000 ml/ ha	40.00	58.75	23.53	22.08	22.33	30.45	32.86
	T_{11}	25 DAT PI to B	0.3 G 5 SC	20 kg/ ha 1000 ml/ ha	26.00	58.75	39.21	28.22	23.86	33.18	34.87
	T_{12}	N + 25 DAT PI to B	0.3 G 5 SC	1000 g/ ha + 20 kg/ ha 1000 ml/ ha	40.00	62.5	49.67	30.67	27.41	36.36	41.10
Carbofuran	T_{13}	N 25 DAT	3 G 3 G	2000 g/ ha 25 kg/ ha	26.00	58.75	8.50	18.40	10.15	18.18	23.33
Untreated control (Water spray)	T_{14}	-	-	-	-	-	-	-	-	-	-

500 g/ha + 10 kg/ha (T_7) with 0.99/hill while lowest was registered in cartap hydrochloride 4G @ 125 g/ha+20 kg/ha+50 SP @ 1000 g/ha (T_6) with 0.52/hill.

From the perusal of data (Table 5), it was clear that highest reduction of population was noticed in cartap hydrochloride 4G @ 125 g/ha + 20 kg/ha + 50 SP @ 1000 g/ha (T_6) with 70.07% followed by flubendiamide 0.7G @ 625 g/ha + 12.5 kg/ha + 20 WDG @ 125 g/ha (T_3) with 54.85% while lowest reduction was noticed in carbofuran 3G @ 2000 g/ha + 25 kg/ha (T_{13}) with 23.33% and fipronil 0.3G @ 1000 g/ha + 5 SC @ 1000 ml/ha (T_{10}) with 32.86% reduction over control.

Superiority of chlorantraniliprole in being less toxic to spiders was reported by Sitesh *et al.* (2015); Jafar *et al.* (2013); Mange and Sachan (2013). Spider population gradually increased and reached to a maximum of 2.37/hill in untreated plot at 65 DAT. At each period of observation some adverse effect of test molecules was observed.Comparatively, cartap hydrochloride and flubendiamide showed least population existence of spiders and also made similar observationswith Sharanappa*et al.* (2019); Jafar *et al.* (2013). Contrastingly, maximum population of spiders were reported in cartap hydrochloride treated plots by Singh *et al.* (2015); Karthikeyan *et al.* (2007). Overall, from the present study carbofuran, fipronil and chlorantraniliprole were found to be relatively safer molecules against spiders.*Figures in the parenthesis are transformed values; $ = Insecticides applied in N: Nursery, at 25 DAT, PI to B : at Panicle initiation to Booting stage

Conclusion

It is important to choose the correct insecticide that is most effective against the targeted insect pest but to maintain the ecological balance of natural enemy populations in the field. The results of the study also suggest that the reduction in pest populations were also influnced by the presence of natural enemies in the area rather than climatic parameters. The weather conditions did not affect the predation and parasitism by natural enemies, while the natural enemies were dependent on the pest populations.

The present study clearly disclosed that all chemicals caused mortality of coccinellids and spiders. Cartap hydrochloride and flubendiamide insecticides were found to be the most toxic since they have caused highest mortality of beneficials while, carbofuran followed by fipronil and chlorantraniliprole were safest resulting in lowest mortality of the beneficials. They can be suitably integrated in the integrated pest management (IPM) for the best management of insect pests of rice.

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