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Field Evaluation of Newer Insecticides for the Management of Sucking Pests in Cotton (*Gossypium hirsutum* L.)

P. Ashish Kamal, Shivaray Navi, L. Vijaykumar, C. Shashi Kumar, G. Somu, B. Rajendra and N. M. Chikkarugi
AICRP on Cotton, Haradanahalli Farm,
KVK Campus, Chamarajanagara - 571 127
e-Mail : naviss1977@gmail.com

Authors Contribution

P. Ashish Kamal : Conceptualization, experimentation and data analysis;
Shivaray Navi; G. Somu & L. Vijaykumar : Conceptualization, guidance, editing and supervision;
C. Shashi Kumar & B. Rajendra : Designing and layout of the experimentation;
N. M. Chikkarugi : Edition of manuscript and final submission

Corresponding Author :
P. Ashish Kamal

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Abstract

To determine the efficacy of newer insecticides against major sucking pests in cotton, a field study was undertaken at All India Co-ordinated Research Project on Cotton, Chamarajanagar, University of Agricultural Sciences, Bangalore during 2021-22. Totally three sprays were taken at different intervals by using seven insecticides. The sucking pests population count were observed at pre and three, seven and fourteen days after each spray. The mean of three sprays evidenced the superiority of flonicamide 50 WG by recording least number of leafhoppers (2.17/3 leaves) and aphids (10.34/3 leaves) population with percent reduction of 74.41 per cent and 68.54 per cent, respectively followed by dinotefuran 20 SG @ 0.3 g/L and pyriproxyfen 10 EC @ 2 mL/L. Among the different newer molecules, significantly less incidence of thrips (3.47/3 leaves) and whiteflies (1.10/3 leaves) were noticed in spinetoram 11.7 SC treated plots with maximum percent reduction. Among the treatments, the higher seed cotton yield (2020 kg/ha) was recorded in flonicamide 50 WG with 90.20 per cent increase over control.

Keywords : Cotton, *Amrasca devastanse, Aphis gossypii, Thrips tabaci, Bemicia tabaci*

Cotton, *Gossypium hirsutum* L. (Family: Malvaceae), is a major fibre and cash crop of global importance (Murali and Khan, 2022). It is farmed in India on an area of 10.2 million acres, producing 32.5 million bales (Anonymous, 2022). It is a crucial raw resource for many Asian agro-based industries. As a result, it provides a living for millions of people in farms, ginning factories, textile mills, edible oil and soap companies and other industries; thus, recognized as the life blood of many Asian economies. The major factor responsible for the low productivity and quality deterioration of cotton is the severe attack of insects/pests from sowing to harvesting (Ban *et al.*, 2010). In India cotton crops are known to be attacked by 162 species of insect pests from sowing to harvesting and which causes loss up to 50-60 per cent (Agarwal *et al.*, 1984). Among the sucking pests, Thrips, *Thrips tabaci* (Lindeman), leafhoppers, *Amrasca devastans* (Ishida), whiteflies, *Bemisia tabaci* (Gennadius) and Aphids, *Aphis gossypii* Glover are the major pests of constraints in growth and development of cotton crop. These sucking pests occur at all the stages of crop growth and are responsible for indirect yield losses. A reduction of 22.85 per cent in seed cotton yield due to sucking pests has been reported by Satpute *et al.* (1990). The heavy infestation of nymphs and adults of sucking pests resulted in leaf yellowing, wrinkled leaves and leaf distortion. They also secrete honey dew which leads to the growth and development of shooty-mould fungus (*Capnodium* sp.) on leaves. The fungus inhibits the photosynthetic activity of the plants resulting in chlorosis that affects the seed cotton yield. Moreover, whitefly also acts as a vector to transmit leaf curl disease in cotton. Insecticides are used in pest management to keep insect numbers below the ETL in better and faster successions, allowing yield to be increased. There fore, with a view to find efficacy of new novel insecticides, this experiment has been conducted for management of sucking pests in cotton.

Material and Methods

The experiment was conducted at All India Co-ordinated Research Project, Chamarajanagar during the *kharif* season of 2021-22 to evaluate the comparative efficacy of novel molecules against sucking pests of cotton. The trial was laid out in Randomized Block Design with eight treatments and three replications. The popular growing cotton hybrid Bahubali B.G II was sown during last week of July with the spacing of 90x60 cm between rows and plants respectively in a plot size of 5x4 meters. All the standard agronomic practices were adopted as prescribed by UAS, Bangalore except plant protection practices for sucking pests. Totally three sprays with different insecticides were taken on ETL basis at fifteen days intervals by using Knapsack spray. The data were recorded on five tagged plants in each treatment. Pre-treatment observations of all sucking pests from three leaves (Top, middle and bottom leaves) were recorded a day before the imposition of first spray. Post treatment data on sucking pests were recorded at 3, 7 and 14 days after each spray. Mean of all three observations were calculated and for that percent reduction over control was also worked out. The activities of natural enemies like coccinellids and spiders were also recorded on five plants before and fourteen days after the last spray. Seed cotton yield was recorded at each picking and all the data were subjected to statistical analysis for comparison of treatments.

Results and Discussion

Leafhoppers, *Amrasca Devastanse*

Population of leafhoppers a day before first treatment imposition ranged from 7.41 to 8.95 per three leaves and there was no significant difference among different treatments. Lowest population of leaf hoppers after 7 and 14 days was noticed in flonicamid 50 WG @ 0.3 g/l (/3.79 and 4.68/3 leaves, respectively) and found superior followed by dinotefuran 20 SG @0.3 g/l. After the second spray, leafhopper population was reduced significantly in all the treatments and the minimum population of leafhoppers (1.57/3 leaves) was noticed in flonicamid 50 WG @ 0.3 g/L sprayed plot. Similar trend was noticed in third spray also at different interventions.

The mean leafhopper population after the three spray schedules across the treatments indicated that the least leafhopper population was recorded in flonicamid 50 WG @ 0.3 g/L (2.17/3 leaves) and found significantly superior over other treatments. This was followed by dinotefuran 20 SG @ 0.3 g/l and pyriproxyfen 10 EC @ 2 ml/l with 2.37 and 2.76 leafhoppers/3 leaves, respectively. Among all the insecticides tested after three sprays, for the management of leafhoppers, highest per cent reduction of leafhopper population was recorded in flonicamid 50 WG @ 0.3 g/L over untreated control (74.41%). Next best treatments were dinotefuran 20 SG @ 0.3 g/L and pyriproxyfen 10 EC @ 2 mL/L which recorded 72.05 and 67.45 per cent reduction, respectively. The present results are in conformity with Naik *et al.* (2017) who reported that flonicamid 50 WG has recorded the least leafhopper population of 2.19 leafhoppers /3 leaves under HDPS among all the other treatments. Further Meghana *et al.* (2018) also reported that spraying of flonicamid 50 WG @ 0.3 g/L was found effective in controlling the leafhopper population followed by dinetofuran 20 SG @ 0.3 g/L. (Table 1). The findings are in confirmation with Santhoshi *et al.* (2022)

Aphids, *Aphis Gossypii*

Before the application of insecticides, aphids population was uniform and varied between 36.05 to

TABLE 1

Bio-efficacy of newer insecticides against cotton leafhoppers

Treatments	Dose (g or ml/ha)	Leafhoppers/ 3 leaves										Pooled mean	% reduction over control
		I spray				II spray			III spray				
		1 DBS	3 DAS	7 DAS	14 DAS	3DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
Spinetoram 11.7 SC	420	7.41 (2.90) a	6.13 (2.67) b	5.06 (2.46) bc	5.95 (2.46) bc	3.69 (2.17) b	2.65 (1.91) bc	3.14 (2.04) c	2.15 (1.78) b	1.05 (1.43) bc	0.93 (1.39) c	3.34 (2.02) c	60.60
Pyriproxyfen 10 EC	1000	7.63 (2.94) a	6.50 (2.74) b	4.51 (2.35) cde	5.40 (2.53) cd	3.14 (2.03) b	1.89 (1.70) cde	2.38 (1.84) cd	1.39 (1.55) b	0.61 (1.27) cde	0.50 (1.23) cd	2.76 (1.86) de	67.45
Dinotefuran 20 SG	150	8.28 (3.05) a	6.25 (2.69) b	4.04 (2.24) de	4.93 (2.44) de	2.67 (1.92) b	1.26 (1.50) de	1.75 (1.66) de	0.77 (1.33) b	0.53 (1.24) de	0.42 (1.19) de	2.37 (1.76) ef	72.05
Spiromesifen 240 SC	600	8.95 (3.15) a	7.67 (2.94) a	5.81 (2.61) b	6.70 (2.78) b	4.45 (2.34) a	2.72 (1.93) b	3.28 (2.07) b	2.30 (1.82) a	1.77 (1.66) b	1.66 (1.63) b	3.88 (2.16) b	54.24
Diafenthiuron 50 WP	600	9.50 (3.24) a	8.02 (3.00) a	4.78 (2.40) cd	5.67 (2.58) c	3.42 (2.10) b	2.20 (1.79) cd	2.72 (1.93) c	1.74 (1.65) a	0.78 (1.33) cd	0.67 (1.29) c	3.02 (1.93) cd	64.38
Flonicamide 50 WG	150	8.15 (3.03) a	6.16 (2.68) b	3.79 (2.19) e	4.68 (2.38) e	2.39 (1.84) b	1.09 (1.44) e	1.57 (1.60) e	0.59 (1.26) b	0.36 (1.16) e	0.25 (1.12) e	2.17 (1.70) f	74.41
Imidacloprid 200 SL	125	7.81 (2.97) a	6.53 (2.74) b	4.91 (2.43) c	5.80 (2.61) c	3.55 (2.13) b	2.31 (1.82) c	2.80 (1.95) c	1.82 (1.68) b	0.92 (1.39) c	0.81 (1.35)c	3.14 (1.97) cd	62.97
Untreated Control		8.50 (3.08) a	8.60 (3.10) a	9.12 (3.18) a	9.94 (3.31) a	9.63 (3.26) a	9.22 (3.20) a	9.30 (3.21) a	8.40 (3.07) a	7.12 (2.85) a	6.19 (2.68)a	8.48 (3.07) a	-
CD @ 5%		NS	0.52	0.31	0.42	0.48	0.32	0.28	0.31	0.27	0.22	0.30	
S.Em ±			0.17	0.10	0.13	0.15	0.10	0.09	0.10	0.09	0.07	0.17	

* DBS: Day before spraying; DAS: Days after spraying; NS: Non-significant; Values in the paranthesis followed by common letters are non- significant at p= 0.05. Figures in the parenthesis indicate $\sqrt{x+0.5}$ transformed values.

38.33/ per three leaves. The data of 7 and 14 days after first spray indicated the superiority of insecticide flonicamid 50 WG @ 0.3g/L by recording lower aphid population (19.68 and 21.80/3 leaves, respectively) which were on par with dinotefuran 20 SG @ 0.3 g/L followed by pyriproxyfen10 EC @ 2 mL/L. The similar trend of aphid population reduction was seen during the second and third spray also wherein flonicamid 50 WG @ 0.3g/L was found most effective in reducing aphid population at different observation periods (Table 2).

The pooled data of all three sprays also indicated the superiority of flonicamid 50 WG @ 0.3g/L, where we could recorded least aphid population of 10.3/3 leaves followed by dinotefuran 20 SG @ 0.3 g/L with 11.69/3 leaves. These two insecticides were on par with each other. When percent reduction of aphid over control is concerned, highest per cent reduction of aphids population (68.54%) was recorded in flonicamid 50 WG @ 0.3 g/L over untreated control. Next best treatments were dinotefuran 20 SG @ 0.3 g/L and pyriproxyfen 10 EC @ 2 mL/L which were recorded 64.43 and 60.66 per cent reduction, respectively. Similar results were also reported by Gaurkhede *et al*. (2015) that the least aphid population in the plots treated with flonicamid 50 WG @ 0.3g/L (2.96 aphids/leaf) and was on par with dinotefuran 20 SG @ 0.3 mL/L (3.50 aphids/leaf). Sreenivas *et al.* (2015) reported the superiority of dinotefuran 20 per cent SG against Bt cotton sucking pests at varied doses such as 15, 20, 25 and 30 g a.i/ha. The effects of treatments significantly differed from the untreated control and standard check after 3, 7, 10 and 14 days after application.

In case of controlling leafhoppers and aphids, Flonicamid has been found effective in controlling the sucking pests efficiently. Flonicamid is a highly specific insecticide that offers long-term control over leafhoppers and aphids and other sucking insects. This insecticides mode of action was shown to be distinct from neonicotinoids, which operate as agonists on the insect nicotinic acetylcholine receptor (nAChR), as it quickly suppressed the feeding behaviour of leafhoppers and aphids.

Thrips, *Thrips Tabaci*

Thrips population a day before spray during the first treatment imposition ranged from 8.28 to 8.97 per three leaves and there was no significant difference among different treatments. The most successful treatment for controlling the thrips population was spinetoram 11.7 SC @ 0.5 mL/L by evidencing lowest thrips population (6.10/3 leaves) during 7 days after first spray, which was on par with flonicamid 50 WG @ 0.3 g/L. These two treatments are equally effective in controlling thrips population. Remaining insecticidal treatments were also found effective in reducing the thrips population when compared to untreated control. This trend of reduction in thrips population were seen in different intervals of observation and significantly lowest pest population were recorded in similar treatments in second and third sprays (Table 3)

The mean population of thrips after post treatment was analyzed and was revealed that significantly lowest mean numbers of thrips (3.47/3 leaves) were observed in spinetoram 11.7 SC @ 0.5 mL/L which was on par with flonicamid 50 WG @ 0.3 g/L by recording a population of 3.62/3 leaves. Among all the insecticides tested for the management of thrips, highest per cent reduction of thrips population (70.21%) was recorded in spinetoram 11.7 SC @ 0.5 mL/L, over untreated control. Next best treatments were flonicamid 50 WG @ 0.3 g/L and pyriproxyfen 10 EC @ 2 mL/L, which recorded 68.92 and 64.54 per cent reduction over control, respectively. The present results are in agreement with the findings of Rao *et al.* (2022) who reported that application of spinetoram 11.7 SC was found to be the most effective for the management of thrips, where they proved by recording minimum thrips population of 8.4/3 leaves, followed by profenofos 50 EC (13.8/3 leaves) and fipronil 5 SC (15.7/3 leaves). Further, the results of the Matharu and Tanwar (2020) also revealed that minimum population of 3.03 thrips /leaf was recorded in spinetoram 11.7 SC treatment followed by diafenthiuron 50 WP and thiamethoxam 25 WG with 8.70 and 12.07 thrips/leaf, respectively after 10 days of the spray.

TABLE 2

Bio-efficacy of newer insecticides against cotton aphids

Treatments	Dose (g or ml/ha)	Aphids/ 3 leaves										Pooled mean	% reduction over control
			I spray			II spray			III spray				
		1 DBS	3 DAS	7 DAS	14 DAS	3DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
Spinetoram 11.7 SC	420	37.00 (6.16) a	34.19 (5.93) b	26.80 (5.27) bc	28.92 (5.47) bc	24.10 (5.01) b	12.67 (3.70) bc	15.25 (4.03) bc	12.95 (3.73) b	3.73 (2.25) bc	3.75 (2.18) bc	15.97 (3.89) bc	51.41
Pyriproxyfen 10 EC	1000	37.88 (6.24) a	32.75 (5.81) b	23.24 (4.92) de	25.36 (5.13) cde	20.85 (4.67) b	9.11 (3.18) de	11.69 (3.56) cde	9.33 (3.21) b	3.21 (1.74) de	1.73 (1.65) cde	12.93 (3.45) de	60.66
Dinotefuran 20 SG	150	36.53 (6.13) a	31.40 (5.69) b	21.42 (4.73) ef	23.54 (4.95) de	18.16 (4.38) b	7.92 (2.99) ef	10.50 (3.39) de	8.14 (3.02) b	3.02 (1.54) ef	1.02 (1.42)de	11.69 (3.26) ef	64.43
Spiromesifen 240 SC	600	36.05 (6.09) a	35.45 (6.04) a	28.40 (5.42) b	30.52 (5.61) b	26.01 (5.20) a	14.27 (3.91) b	16.85 (4.23) b	14.49 (3.94) a	3.94 (2.39) b	4.42 (2.33) b	17.26 (4.06) b	47.49
Diafenthiuron 50WP	600	37.63 (6.22) a	33.31 (5.86) a	24.26 (5.03) cd	26.38 (5.23) bcd	21.87 (4.78) a	10.13 (3.34) cd	12.71 (3.70) bcd	10.35 (3.37) b	3.37 (1.90) cd	2.33 (1.82) bcd	13.81 (3.59) cd	57.98
Flonicamide 50 WG	150	36.27 (6.11) a	31.14 (5.67) b	19.68 (4.55) f	21.80 (4.77) e	16.43 (4.17) b	5.93 (2.63) f	8.51 (3.08) e	6.12 (2.67) b	2.67 (1.42) f	0.69 (1.30) e	10.34 (3.05) f	68.54
Imidacloprid 200 SL	125	37.06 (6.17) a	32.44 (5.78) b	25.28 (5.13) cd	27.40 (5.33) bcd	22.89 (4.89) b	11.15 (3.49) cd	13.73 (3.84) bcd	11.37 (3.52) b	3.52 (2.11) cd	3.15 (2.04) bcd	14.76 (3.73) cd	55.09
Untreated Control		38.33 (6.27) a	37.59 (6.21) a	39.56 (6.37) a	41.68 (6.53) a	41.50 (6.52) a	35.65 (6.05) a	33.85 (5.90) a	33.28 (5.86) a	35.86 (6.07) a	23.09 (4.91) a	32.87 (5.78)a	-
CD @ 5%		NS	0.85	0.77	0.81	0.89	1.11	1.05	1.12	0.57	0.59	0.82	-
S.E m±			0.28	0.25	0.26	0.29	0.36	0.34	0.36	0.18	0.19	0.26	-

* DBS: Day before spraying; DAS: Days after spraying; NS: Non-significant; Values in the paranthesis followed by common letters are non- significant at p= 0.05. Figures in the parenthesis indicate $\sqrt{x+0.5}$ transformed values.

TABLE 3

Bio-efficacy of newer insecticides against cotton thrips

Treatments	Dose (g or ml/ha)	Thrips/ 3 leaves										Pooled mean	% reduction over control
		I spray				II spray			III spray				
		1 DBS	3 DAS	7 DAS	14 DAS	3DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
Spinetoram 11.7 SC	420	8.62 (3.10) ^{a}	7.01 (2.83) ^{d}	6.10 (2.66) ^{d}	7.36 (2.89) ^{c}	4.41 (2.33) ^{d}	1.11 (1.45) ^{d}	2.68 (1.92) ^{d}	1.42 (1.56) ^{d}	0.48 (1.22) ^{d}	0.37 (1.17) ^{c}	3.47 (1.99) ^{f}	70.21
Pyriproxyfen 10 EC	1000	8.87 (3.14) ^{a}	7.66 (2.94) ^{bcd}	6.43 (2.73) ^{cd}	7.93 (2.99) ^{c}	5.72 (2.59) ^{bcd}	2.16 (1.78) ^{cd}	3.73 (2.17) ^{cd}	2.46 (1.86) ^{bcd}	0.84 (1.36) ^{cd}	0.72 (1.31) ^{c}	4.13 (2.16) ^{d}	64.54
Dinotefuran 20 SG	150	8.28 (3.21) ^{a}	8.07 (3.01) ^{abc}	6.56 (2.75) ^{cd}	8.07 (3.01) ^{c}	5.86 (2.62) ^{abc}	2.34 (1.83) ^{bc}	3.91 (2.22) ^{cd}	2.66 (1.91) ^{abc}	0.95 (1.40) ^{bcd}	0.83 (1.35) ^{c}	4.27 (2.19) ^{d}	63.34
Spiromesifen 240 SC	600	8.58 (3.09) ^{a}	7.37 (2.89) ^{cd}	7.07 (2.84) ^{bc}	8.61 (3.10) ^{bc}	6.40 (2.72) ^{cd}	2.57 (1.89) ^{bc}	4.24 (2.29) ^{bc}	2.99 (2.00) ^{cd}	1.52 (1.59) ^{ab}	1.40 (1.55) ^{bc}	4.75 (2.31) ^{c}	59.22
Diafenthiuron 50WP	600	8.97 (3.31) ^{a}	8.76 (3.12) ^{a}	6.75 (2.78) ^{bcd}	8.37 (3.06) ^{bc}	6.16 (2.68) ^{a}	2.51 (1.87) ^{bcd}	4.08 (2.25) ^{bc}	2.83 (1.96) ^{a}	1.14 (1.46) ^{a}	1.02 (1.42) ^{bc}	4.49 (2.25) ^{cd}	61.45
Flonicamide 50 WG	150	8.83 (3.13) ^{a}	7.42 (2.90) ^{cd}	6.15 (2.67) ^{d}	7.67 (2.94) ^{c}	5.19 (2.49) ^{cd}	1.16 (1.47) ^{bcd}	2.73 (1.93) ^{cd}	1.47 (1.57) ^{cd}	0.61 (1.27) ^{bcd}	0.47 (1.21) ^{c}	3.62 (2.03) ^{ef}	68.92
Imidacloprid 200 SL	125	8.45 (3.23) ^{a}	8.18 (3.03) ^{ab}	7.55 (2.92) ^{b}	9.44 (3.23) ^{b}	7.23 (2.87) ^{ab}	3.42 (2.10) ^{ab}	5.13 (2.48) ^{ab}	3.88 (2.21) ^{ab}	2.17 (1.78) ^{cd}	2.05 (1.75) ^{b}	5.54 (2.48) ^{b}	52.44
Untreated Control		8.58 (3.10) ^{a}	8.68 (3.11) ^{a}	11.82 (3.58) ^{a}	13.67 (3.83) ^{a}	12.00 (3.61) ^{a}	10.32 (3.36) ^{a}	12.03 (3.61) ^{a}	11.01 (3.47) ^{a}	10.07 (3.33) ^{a}	9.24 (3.20) ^{a}	11.65 (2.20) ^{a}	-
CD @ 5%		NS	0.42	0.43	0.51	0.55	0.42	0.36	0.42	0.34	0.29	0.39	-
SEm±			0.14	0.14	0.17	0.18	0.13	0.11	0.14	0.11	0.09	0.12	-

* DBS: Day before spraying; DAS: Days after spraying; NS: Non-significant; Values in the paranthesis followed by common letters are non- significant at p= 0.05. Figures in the parenthesis indicate $\sqrt{x+0.5}$ transformed values.

Whiteflies, *Bemicia Tabaci*

During the evaluation, an initial mean population of whiteflies ranged from 5.29 to 6.96 per three leaves in various treatments and the difference was non-significant. At seven days after first spray, among the different chemical treatments, spinetoram 11.7 SC @ 0.5 mL/L was recorded least population of white flies (1.31/3leaves) and it was at par with flonicamid 50 WG @ 0.3g/L and recorded a whitefly population of 1.49/3 leaves. Other treatments were also found effective in reducing the whiteflies population as compared to control. During different intervals of second and third spray *i.e.,* at 7 and 14 days after sprays, a similar trend in reducing the pests was observed. Here also the above said treatments were found superior as compared to other treatments for the management of whiteflies (Table 4).

The mean number of whiteflies were analyzed and presented in Table 4. The lowest mean population of 1.10 and 1.29 whiteflies/3 leaves were recorded in the plots treated with spinetoram 11.7 SC @ 0.5 mL/L and flonicamid 50 WG @ 0.3 g/L, respectively and these treatments were on par with each other. This was followed by the treatments *viz*., pyriproxyfen 10 EC @ 2 mL/L (1.47/3 leaves) and dinotefuran 20 SG @ 0.3 g/L (1.83/3 leaves), which are significantly different from other treatments. Among all the insecticides tested after three sprays for the management of whiteflies, highest per cent reduction of whiteflies population (83.79%) was recorded in spinetoram 11.7 SC @ 0.5 mL/L over untreated control. Next best treatments were flonicamid 50 WG @ 0.3 g/L and pyriproxyfen 10 EC @ 2 mL/L, which recorded 81.00 and 78.35 per cent reduction, respectively. The present results are in close conformity with Rajasekar *et al.* (2017) who reported the lowest whitefly population in spinetoram 12 SC @ 1 mL + carbendazim 50WP @ 1.0 g. Further, Ghelani *et al*. (2014), also observed that the spray of flonicamid significantly caused maximum mortality of whiteflies (71.47%) and it was statistically at par with acetamiprid (69.83%) and imidacloprid (66.17%), followed by dinotefuron (63.06%), thiamethoxam (62.76%). The superiority of spinetoram, in the control of cotton thrips and whiteflies is due to which spinetoram, a xylem mobile insecticide, affects nicotinic acetylcholine receptors and amino butyric acid (GABA) receptors present on postsynaptic membranes in insect nervous systems, resulting in abnormal neural transmission.

Toxicity of Newer Insecticides Against Natural Enemies in Cotton Ecosystem.

During the experimental period, the population of natural enemies was recorded in pre and post treatment (14 days after 3rd spray) of insecticides. Insecticide interventions did not affect the predatory activity (coccinellids and spider) in all the three sprays as there was no significant variation among treatments even before and after application of insecticides. However, the predatory activity in imidacloprid 200 SL @ 0.3 mL/L treated plots was numerically less as compared to control plot (Table 5). Among the different treatments, higher population of natural enemies were recorded in the plot treated with pyriproxyfen 10 EC @ 2 mL/L with lesser per cent reduction over control (28.66%) and found safer to natural enemies followed by flonicamid 50 WG @ 0.3 g/L (30.29% reduction), dinotefuran 20 SG @ 0.3 g/L (30.61%) followed by spinetoram 11.7 SC @ 0.5 mL/L (34.52%), spiromesifen 22.9 SC @ 1.2 mL/ L (37.45%) and diafenthiuron 50 WP @ 0.8 g/L (38.43 %) reduction over control. Similar results were found with Medina *et al.* (2003) on larvae of *Chrysoperla zastrowi* when toxicity and absorption of Azadirachtin, Diflubenzuron, Pyriproxyfen and Tebufenozide were topically applied on the larvae higher compared to other IGR's and it is due to the potent juvenile hormone mimic. Pyriproxyfen had relatively lesser toxicity when compared with other newer insecticides where in higher population of natural enemies was observed when treated with pyriproxyfen may be due to the unique mode of action of the insect growth regulator, Pyriproxyfen affects the morphogenesis, reproduction, and embryogenesis of insects.

TABLE 4

Bio-efficacy of newer insecticides against cotton whiteflies

Treatments	Dose (g or ml/ha)	Whiteflies/ 3 leaves										Pooled mean	% reduction over control
		I spray				II spray			III spray				
		1 DBS	3 DAS	7 DAS	14 DAS	3DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
Spinetoram 11.7 SC	420	6.96 (2.82) a	5.88 (2.62) a	1.31 (1.52) e	2.47 (1.86) e	1.90 (1.70) a	0.52 (1.23) e	0.67 (1.29) e	0.58 (1.26) a	0.23 (1.11) e	0.16 (1.08) e	1.10 (1.41) f	83.79
Pyriproxyfen 10 EC	1000	5.83 (2.61) a	4.85 (2.42) b	1.67 (1.64) de	2.90 (1.97) de	2.38 (1.84) b	0.96 (1.40) de	1.15 (1.47) de	1.04 (1.43) b	0.47 (1.21) de	0.36 (1.16) de	1.47 (1.53) e	78.35
Dinotefuran 20 SG	150	5.29 (2.51) a	4.31 (2.30) b	2.12 (1.77)c d	3.46 (2.11) cd	2.94 (1.99) b	1.13 (1.46) cd	1.42 (1.55) cd	1.31 (1.52) b	0.72 (1.31) cd	0.61 (1.27) cd	1.83 (1.64) d	73.04
Spiromesifen 240 SC	600	5.67 (2.58) a	4.69 (2.39) b	2.73 (1.93) bc	4.13 (2.27) bc	3.61 (2.15) b	2.02 (1.74) bc	2.24 (1.80) bc	2.13 (1.77) b	1.15 (1.47) bc	1.04 (1.43) bc	2.47 (1.83)	63.62
Diafenthiuron 50 WP	600	5.56 (2.56) a	4.58 (2.36) b	2.44 (1.85) bc	3.97 (2.23) bc	3.45 (2.11) b	1.58 (1.61) bc	1.76 (1.66) bc	1.65 (1.63) b	0.93 (1.39) bc	0.82 (1.35) bc	2.19 (1.75) c	67.74
Flonicamide 50 WG	150	6.94 (2.82) a	5.85 (2.62) a	1.49 (1.58) de	2.71 (1.93) de	2.20 (1.79) a	0.70 (1.30) de	0.90 (1.38) de	0.79 (1.34) a	0.36 (1.17) de	0.25 (1.12) de	1.29 (1.47) ef	81.00
Imidacloprid 200 SL	125	5.89 (2.63) a	4.91 (2.43) b	3.03 (2.01) b	4.55 (2.36) b	4.03 (2.24) b	2.49 (1.87) b	2.60 (1.90) b	2.49 (1.87) b	1.54 (1.59) b	1.43 (1.56) b	2.86 (1.94) b	57.87
Untreated Control		6.86 (2.80) a	6.19 (2.68) a	6.91 (2.81) a	8.05 (3.01) a	8.47 (3.08) a	6.54 (2.75) a	7.00 (2.83) a	7.01 (2.83) a	5.43 (2.54) a	5.32 (2.51) a	6.79 (2.78) a	-
CD @ 5%		NS	0.42	0.30	0.30	0.32	0.32	0.33	0.34	0.20	0.21	0.28	-
SEm±			0.13	0.09	0.10	0.10	0.10	0.11	0.11	0.06	0.06	0.09	-

* DBS: Day before spraying; DAS: Days after spraying; NS: Non-significant; Values in the paranthesis followed by common letters are non- significant at p= 0.05. Figures in the parenthesis indicate √x+0.5 transformed values.

TABLE 5

Bio efficacy of insecticides on natural enemies of cotton

Treatments	Dose (g or ml/ha)	Number of natural enemies / plant (Coccinellids and spiders)			Seed cotton yield (kg/ha)	% Increase over control	B:C Ratio
		Before Spray	14 days after 3rd Spray	% reduction over control			
Spinetoram 11.7 SC	420	3.53 (2.13) [a]	2.01 (1.73) [a]	34.52	1757 [ab]	65.44	1.32
Pyriproxyfen 10 EC	1000	3.68 (2.15) [a]	2.19 (1.76) [a]	28.66	1972 [a]	85.68	2.19
Dinotefuran 20 SG	150	3.59 (2.13) [a]	2.13 (1.77) [a]	30.61	1898 [a]	78.71	2.12
Spiromesifen 22.9 SC	600	3.43 (2.09) [a]	1.92 (1.71) [a]	37.45	1479 [b]	39.26	1.09
Diafenthiuron 50 WP	600	3.40 (2.10) [a]	1.89 (1.70) [a]	38.43	1782 [ab]	67.79	1.66
Flonicamid 50 WG	150	3.65 (2.16) [a]	2.14 (1.77) [a]	30.29	2020 [a]	90.20	2.17
Imidacloprid 17.8 SL	125	3.13 (2.26) [a]	1.72 (1.65) [a]	43.97	1507 [b]	41.90	1.55
Control	-	4.11 (2.26) [b]	3.07 (2.02) [b]	-	1062 [c]	-	0.89
CD @ 5%		NS	0.27	-	0.64	-	-
SEm		NS	0.09	-	0.21	-	-

*DBS: Day before spraying; DAS: Days after spraying; NS: Non-significant; Values in the paranthesis followed by common letters are non- significant at p= 0.05. Figures in the parenthesis indicate $\sqrt{x+0.5}$ transformed values.

Seed Cotton Yield (kg/ha)

The data on seed cotton yield revealed that significantly higher yield (2020 kg/ha) was recorded in flonicamid 50 WG @ 0.3 g/L with 90.20 per cent increase over control which was on par with pyriproxyfen 10 EC @ 2 mL/L and dinotefuran 20 SG @ 0.3 g/L which recorded 1972 and 1898 kg/ha and differed significantly from rest of the treatments. Untreated control recorded 1062 kg/ha seed cotton yield which was significantly lower than all the treatment plots (Table 5). The next best treat,ents in obtaining the yields were diafenthiuron 50 WP @ 0.8 g/L, spinetoram 11.7 SC @ 0.5 mL/L, imidacloprid 200 SL @ 0.3 mL/L and spiromesifin 22.9 SC @ 1.2 mL/L, which were recorded 1782, 1757, 1507 and 1479 kg/ha with 67.79, 65.44, 41.90 and 39.26 per cent increase over untreated control, respectively. Similarly, the highest cost benefit ratio (1:2.19) was evidenced in pyriproxyfen 10 EC @ 2 mL/L treatment followed by flonicamid 50 WG @ 0.3 g/L (1:2.17), dinotefuran 20 SG @ 0.3 g/L (1:2.12), diafenthiuron 50 WP @ 0.8 g/L (1:1.66), Spinetoram 11.7 SC @ 0.5 mL/L (1:1.32), imidacloprid 200 SL @ 0.3 mL/L (1:1.55) and spiromesifin 22.9 SC @ 1.2 mL/L (1:1.09) and the least cost benefit ratio of 1:0.89 was recorded in untreated control.

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