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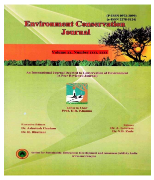

Relative bioefficacy of different insecticides against sucking pest complex of tomato (*Lycopersicum esculentum* L.) and their effect on natural enemies present under field condition

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ABSTRACT

The field experiment was carried out on tomato in the *Rabi* season of 2019-20 at the Vegetable Research Farm, Institute of Agricultural Science, Banaras Hindu University, Varanasi, India. The crop variety, Arka Vikas (Selection 22) was selected to evaluate the bioefficacy of nine different insecticidal treatments against the sucking pest complex and the natural enemies in tomato under field conditions. Two sprays at 15 days intervals of ten treatments with three replications were applied. The treatments were Diafenthiuron 50% WP, Abamectin 1.8% EC, Buprofezin 25% SC, Indoxacarb 14.5% SC, Spinosad 45% SC, Chlorantraniliprole 18.5% SC, Pymetrozine 50% WG, Flonicamid 50% WG, and Lancer Gold (50 + 1.8) % SP and control (water spray). Observations were recorded one day before and 1^{st}, 3^{rd}, 5^{th}, 7^{th}, 10^{th}, and 15^{th} days after each spray. For controlling Whitefly (*B. tabaci*), Lancer gold was observed to be the best (76.98%), followed by Pymetrozine (69.03%) and Flonicamid (59.39%). At the same time, Flonicamid was excellent (70.62%) in controlling Aphids (*A. gossypii*), followed by Lancer gold (67.15%) and Pymetrozine (65.48%). In case of a reduction of damage by Thrips (*T. tabaci*), Lancer gold showed the best result (75.60%), followed by Buprofezin (68.45%) and Flonicamid (65.69%). However, all the treatments showed minute toxicity for the natural enemies; yet Flonicamid and Lancer gold were significantly safer among all of them.

Introduction

Tomato (*Lycopersicon esculentum* L.) is a vital crop among the different vegetables grown throughout the year in our country due to its high commercial and nutritional importance and its wide range of environmental versatility. Tomato has become an important food crop in the world in less than a century. Though tomato is considered as a vegetable, it is a fruit. After the potato, it is the second most widely produced vegetable globally. West Bengal, Andhra Pradesh, Bihar, Karnataka, Uttar Pradesh, Orissa, Maharashtra, Madhya Pradesh, and Assam are the leading states in our country in tomato production. With the growing demand for this vegetable crop in India and internationally, there has been a significant increase in the region where it was previously uninhabited. As a result, there has been a significant increase in previously documented pests and the emergence of novel invasive pests such as the South American tomato leaf miner, *Tuta absoluta* (Sridhar *et al.,* 2014). Among the many

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pests recorded in India, as many as sixteen have been observed feeding from germination through harvesting, reducing productivity while also degrading the quality. Fruit borer (*Helicoverpa armigera* Hub.), Aphid (*Aphis gossypii* Glover, *Myzus persicae* Sulzer), Jassid (*Amarasca biguttula* Ishida), Serpentine leaf miner (*Liriomyza trifolii* Burgess), Tobacco caterpillar (*Spodoptera litura* Fabricius), Whitefly (*Bemisia tabaci* Gennadius), Thrips (*Thrips tabaci* Lindeman), and Hadda beetle (*Epilachana dodecastigma*) are the most common insect pests of tomatoes. The sucking pests damage plant's cells by sucking the phloem sap directly (Abdel-Baky and Al-Deghairi, 2008), secreting honeydews, and transmitting a variety of viral infections (Khan and Ahmad, 2005). Among the various management methods of these pests, the use of plant products and chemical insecticides are the most popular. Crop protection agents from the organochlorine, organophosphate, and carbamate groups have been utilized to manage insect pests. However, the application of these insecticides produced a coating of persistent poison over the foliage and fruits (Dikshit *et al.,* 2000), and insects developed resistance to them (Cahill *et al.,* 1996; Kramer *et al*., 2012). Their widespread abuse and misuse have resulted in the three, viz: pesticide resistance, pest resurgence, and residues, as well as toxicity dangers to non-target species. As a result, newer compounds with a lower dose of a few grams per hectare must be used to replace these traditional pesticides. This study aimed to assess the efficacy of several pesticides to control the sucking pest complex of tomato, including Diafenthiuron, Abamectin, Buprofezin, Indoxacarb, Spinosad, Chlorantraniliprole, Pymetrozine, Flonicamid 50%, and Lancer Gold.

Material and Methods

The experimental investigation on the bio-efficacy of insecticides against sucking pests, jassid and thrips infesting tomato was carried out at the Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India during *Rabi*, 2020, under field conditions adopting Randomized Block Design. Tomato variety Arka Vikas (Selection 22) of 8-10 cm length were transplanted from the nursery to the main field and standard agronomic practices were followed to raise the crop. The crop was grown without applying any insecticide either in the soil or as a seed treatment. The detail of the insecticides used for the study is described in table 1.

Table 1: List of Insecticides and their doses

SN	Insecticides	Formulations	Trade name	Group of Chemicals	Dosage (g a.i./ha)
1.	Diafenthiuron	50% WP	Pegasus	Thio-urea derivatives	300
2.	Abamectin	1.8% EC	Vertimec	Avermectins	10
3.	Buprofezin	25% SC	Appalaud	Thiadiaznes	250
4.	Indoxacarb	14.5% SC	Avaunt	Oxadiazines	300
5.	Spinosad	45% SC	Tracer	Spinosyns	73
6.	Chlorantraniliprole	18.5% SC	Coragen	Anthanilic Diamides	30
7.	Pymetrozine	50% WG	Chess	Pyridine Azomethine derivatives	200
8.	Flonicamid	50% WG	Ulala	Pyridine carboxamides	60
9.	Acephate 50% + Imidacloprid 1.8% SP	(50 + 1.8) % SP	Lancer gold	Mixture of OP and Neonicotinoid group	518

Application of treatments:

All the insecticides were applied as a foliar spray using a knapsack sprayer. The amount of spray fluid required per plot was estimated by spraying the control plot with water and calculating the required spray fluids. Spray fluid was made by combining a specific amount of water with a pesticide.

$$\text{Amount of formulation} = \frac{\text{Percentage of required concentration x volume required (lit)}}{\text{Concentration of toxicant in insecticide}}$$

The first spray was applied when the pest first reached its economic threshold level (ETL), and the second spray was applied 15 days following the first.

Spraying and observations taken:

Pest population observations were taken on five randomly selected plants before 24 hours and after 1, 3, 5, 7, 10, and 15 days of spraying. The populations were counted on five tagged plants from each plot with three leaves each from the top, three from the middle, and three from the bottom canopy of the plant, with the help of a hand lens. The percent reduction in pest population over control was calculated by using the following formula:

$$\textbf{Percent reduction in population} = \frac{x_1 - x_2}{x_1} \times 100$$

Where,
X_1 = population in control plots
X_2 = population in treated plots

The data were assembled to determine the mean pest infestation in the respective treatment and statistical analysis was used to determine the overall effect of each treatment, standard error, and CD at a 5% level of significance.

Results and Discussion

Effect of newer insecticides against the population of whitefly, *Bemisia tabaci* (Gennadius) in tomato:

First spray:

Table 2 shows that all insecticidal treatments were more effective at reducing whitefly populations than the untreated control. Pre-treatment whitefly populations were uniformly distributed throughout all plots, ranging from 4.20 - 4.80 (average number of whitefly) per plant. The whitefly population after one day of insecticidal spray varied between 3.60 and 4.67 per plant in different insecticidal treatments, while it was 5.07 per plant in the untreated control. After three and five days of spraying, the decreasing rate of the whitefly population remained the same with a range of 3.00 - 4.47 per plant and 1.80 - 4.13 per plant, respectively, and all the treatments were superior to control (5.73 and 6.67 per plant, respectively). After seven days of spraying, the mean population of whitefly gradually increased, and the same trend was also observed in case of ten and fifteen days after spraying. At seven, ten, and fifteen days, the mean population of whitefly varied from 2.40 - 4.73, 2.80 - 5.53, and 3.47 - 6.67 per plant, respectively, whereas in the untreated plot, this population was varied from 7.27, 8.00 and 8.27 per plant respectively. After fifteen days of first spraying, the overall mean population of whiteflies in all the treated plots varied between 3.04 - 5.00 per plant, which is significantly superior to the untreated control (6.58 per plant).After the first, third, fifth, seventh, tenth, and fifteenth day of spray, Lancer gold (T_9) was found to be significantly superior over the rest of the treatments, whereas Pymetrozine (T_7), Flonicamid (T_8), Buprofezin (T_3), Diafenthiuron (T_1), Abamectin (T_2) were found statistically at par with each other in most of the days. Indoxacarb 14.5% SC @ 300 g a.i ha^{-1} was inferior among all insecticidal treatments. Further, the mean percent reduction in whitefly population over control after the first, third, fifth, seventh, tenth and fifteenth days of spray was in descending order: Lancer gold (53.79%)>Pymetrozine(48.78%)>Flonicamid(43.31 %)Buprofezin(40.42%)>Diafenthiuron(37.23%)>Abamectin(36.95%)>Spinosad(32.37%)>Chlorantraniliprole (31.30%)> Indoxacarb (24.01%).

Second spray:

The data presented in table 2 showed that all the insecticidal treatments were significantly superior to the untreated control in reducing the whitefly population after the second spray. The average number of whiteflies one day before the second insecticidal spray in different insecticidal treatments ranged from 3.47-8.87 per plant. The whitefly population after one day of insecticidal spray varied between 2.73 and 5.47 per plant in different insecticidal treatments, while it was 6.60 per plant in the untreated control. After three and five days after spraying, the decreasing rate of the whitefly population remained the same, and it ranged from 1.93-4.87 and 0.73-4.47 per plant, respectively, and all the treatments were superior to control (6.13 and 5.60 per plant respectively). Unlike the first spray, after seven days of the second spraying, the mean population of whitefly gradually decreased, and the same trend was also observed in ten and fifteen days after spraying. At seven, ten, and fifteen days, the mean population of whitefly varied from 0.33-4.00, 0.20-3.80, and 0.13-3.33 per plant, respectively, whereas in the untreated plot, this population was varied from 5.00, 4.73 and 4.47 per plant respectively. After fifteen days of first spraying, the overall mean population of whiteflies in all the treated plots varied between 1.36-4.66 per plant, which is significantly superior to the untreated control (5.91 per plant). After the first, third, fifth, seventh, tenth, and fifteenth day of spray, Lancer gold (T_9) was found to be significantly superior over the rest of the treatments,

Table 2: Effect of newer molecules of insecticides against the population of whitefly, *Bemisia tabaci* (Gennadius) in tomato after first and second application during 2019-20

Treat. No.	Treatments	Dose (g a.i. ha^{-1})	First spray									Second spray								
			Mean population of whitefly per plant*							Post-treatment mean	MRC (%)	Mean population of whitefly per plant*							Post-treatment mean	MRC (%)
			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS		
T_1	**Diafenthiuron**	300	4.73 (2.39)	4.40 (2.32)	3.87 (2.20)	3.13 (2.03)	3.67 (2.15)	4.20 (2.27)	4.93 (2.43)	4.13	37.23	4.93 (2.43)	4.53 (2.35)	4.07 (2.25)	3.13 (2.03)	2.40 (1.84)	1.80 (1.67)	1.20 (1.48)	3.15	46.70
T_2	**Abamectin**	10	4.60 (2.36)	4.40 (2.32)	4.13 (2.26)	3.40 (2.09)	3.93 (2.22)	4.33 (2.30)	5.13 (2.47)	4.28	36.95	5.13 (2.47)	4.67 (2.37)	4.27 (2.29)	3.60 (2.14)	3.07 (2.01)	2.47 (1.86)	1.80 (1.66)	3.57	39.59
T_3	**Buprofezin**	250	4.47 (2.33)	4.20 (2.28)	3.73 (2.17)	2.87 (1.96)	3.47 (2.11)	4.00 (2.23)	4.73 (2.39)	3.92	40.42	4.73 (2.39)	4.13 (2.26)	3.67 (2.15)	2.87 (1.96)	2.07 (1.74)	1.47 (1.56)	0.93 (1.38)	2.84	51.94
T_4	**Indoxacarb**	300	4.80 (2.40)	4.67 (2.38)	4.47 (2.33)	4.13 (2.26)	4.73 (2.39)	5.53 (2.55)	6.67 (2.76)	5.00	24.01	6.67 (2.76)	5.47 (2.54)	4.87 (2.42)	4.47 (2.33)	4.00 (2.23)	3.80 (2.19)	3.33 (2.08)	4.66	21.15
T_5	**Spinosad**	73	4.80 (2.40)	4.60 (2.36)	4.27 (2.29)	3.60 (2.14)	4.07 (2.25)	4.53 (2.35)	5.27 (2.50)	4.45	32.37	5.27 (2.50)	4.93 (2.43)	4.40 (2.32)	4.00 (2.23)	3.40 (2.09)	3.00 (2.00)	2.40 (1.84)	3.91	33.84
T_6	**Clorantraniliprole**	30	4.67 (2.38)	4.60 (2.36)	4.40 (2.32)	3.60 (2.14)	4.27 (2.29)	4.73 (2.39)	5.40 (2.53)	4.52	31.30	5.40 (2.53)	5.13 (2.47)	4.60 (2.36)	4.20 (2.28)	3.93 (2.22)	3.80 (2.19)	3.00 (2.00)	4.30	27.24
T_7	**Pymetrozine**	200	4.27 (2.29)	3.87 (2.20)	3.40 (2.09)	2.20 (1.78)	2.80 (1.94)	3.20 (2.04)	3.87 (2.20)	3.37	48.78	3.87 (2.20)	3.27 (2.06)	2.53 (1.87)	1.60 (1.60)	0.73 (1.31)	0.47 (1.20)	0.33 (1.15)	1.83	69.03
T_8	**Flonicamid**	60	4.27 (2.29)	4.00 (2.23)	3.60 (2.14)	2.67 (1.91)	3.33 (2.08)	3.87 (2.200	4.40 (2.32)	3.73	43.31	4.40 (2.32)	3.93 (2.22)	3.13 (2.03)	2.13 (1.76)	1.60 (1.61)	1.00 (1.41)	0.60 (1.26)	2.40	59.39
T_9	**Lancer gold**	518	4.20 (2.28)	3.60 (2.14)	3.00 (2.00)	1.80 (1.67)	2.40 (1.84)	2.80 (1.94)	3.47 (2.11)	3.04	53.79	3.47 (2.11)	2.73 (1.93)	1.93 (1.71)	0.73 (1.31)	0.33 (1.15)	0.20 (1.09)	0.13 (1.06)	1.36	76.98
T_{10}	**Control**	-	4.47 (2.33)	5.07 (2.46)	5.73 (2.59)	6.67 (2.76)	7.27 (2.87)	8.00 (3.00)	8.87 (3.14)	6.58	-	8.87 (3.14)	6.60 (2.75)	6.13 (2.67)	5.60 (2.56)	5.00 (2.44)	4.73 (2.39)	4.47 (2.33)	5.91	-
SEm±			0.048	0.045	0.043	0.060	0.047	0.041	0.039			0.039	0.043	0.043	0.051	0.047	0.05	0.055		
CD @ 5%			NS	0.134	0.127	0.180	0.141	0.122	0.116			0.116	0.130	0.129	0.153	0.141	0.149	0.165		

PTC- Pre-treatment count;
DAS- Days after spraying;
MRC – Mean reduction over control;
*** Mean of three replications**
Values in parenthesis are square root transformed values;
NS- non-significant

whereas Pymetrozine (T_7), Flonicamid (T_8), Buprofezin (T_3), Diafenthiuron (T_1), Abamectin (T_2) were found statistically at par with each other in most of the days. Indoxacarb 14.5% SC @ 300 g a.i ha^{-1} was inferior among all insecticidal treatments. Further, the mean percent reduction in whitefly population over control after the first, third, fifth, seventh, tenth and fifteenth days of spray was in descending order: Lancer gold (76.98%)> Pymetrozine(69.03%)>Flonicamid(59.39%)>Buprofezin(51.94%)>Diafenthiuron(46.70%)> Abamectin (39.59%)>Spinosad(33.84%)>Chlorantraniliprole(27.24%)>Indoxacarb (21.15%).These findings were strongly supported by Kar (2017) remarking that the whitefly population became zero after three continuous sprayings of Imidacloprid 17.8 % SL@ 175 ml ha^{-1}. Dhar and Bhattacharya (2015) also recorded that spraying Imidacloprid 17.8 % SL for once followed by spraying Spinosad (45 % SC) twice resulted in the highest reduction of whitefly infestation in both in okra and tomato.

Effect of newer insecticides against the population of aphid, *Aphis gossypii* Glover, in tomato: First spray:

The data shown in table 3 revealed that the insect population in all experimental plots were similar (varied from 20.13-21.00 per plant) prior to the imposition of treatments. After spraying, all the test insecticides were determined to be significantly better than the untreated control. The order of effectiveness of various treatments was similar or consistent at various intervals after spraying, with the lowest whitefly population (overall mean value) (irrespective of days after spraying (DAS)) being observed in Flonicamid 50% WG (13.18 aphids/plant) followed by Lancer Gold (50 + 1.8) % SP (13.87 aphids/plant), Pymetrozine 50% WG (14.00 aphids/plant), Diafenthiuron 50% WP (15.19 aphids/plant), which in turn were at par with each other. The next group in terms of effectiveness consisted of Buprofezin 25% SC (15.37 aphids/plant) followed by Abamectin 1.8% EC (15.72 aphids/plant), Spinosad 45% SC (16.29 aphids/plant) and Indoxacarb 14.5% SC (18.50 aphids/plant). On the other hand, the untreated control plot recorded the highest aphid population at 35.74 per plant. The overall mean per cent reduction in aphid population over control was in descending order: Flonicamid 50% WG (63.12%)> Lancer Gold (50 + 1.8) % SP (61.19%)> Pymetrozine 50% WG (60.82%)> Diafenthiuron 50% WP (57.49%)> Buprofezin 25% SC (56.99%)> Abamectin 1.8% EC (56.01%)> Spinosad 45% SC (54.42%)> Chlorantraniliprole 18.5% SC (52.23%)> Indoxacarb 14.5% SC (48.23%).

Second spray:

The data shown in table 3 revealed that the insect population in all experimental plots varied from 17.33-45.33 per plant before the imposition of treatments. After spraying, all the test insecticides were determined to be significantly better than the untreated control. The order of effectiveness of various treatments were similar or consistent at various intervals after spraying, with the lowest whitefly population (overall mean value) (irrespective of DAS) being observed in Flonicamid 50% WG @ 60 g a.i ha^{-1} (8.64 aphids/plant) followed by Lancer Gold (50 + 1.8) % SP (9.66 aphids/plant), Pymetrozine 50% WG (10.15 aphids/plant), Diafenthiuron 50% WP (10.65 aphids/plant). The next group in terms of effectiveness consisted of Buprofezin 25% SC (10.73 aphids/plant), followed by Abamectin 1.8% EC (11.03 aphids/plant), Spinosad 45% SC (11.50 aphids/plant) and Indoxacarb 14.5% SC (13.68 aphids/plant), which in turn were at par with each other. On the other hand, the untreated control plot recorded the highest aphid population at 29.41 per plant. The overall mean per cent reduction in aphid population over control was in descending order: Flonicamid 50% WG (70.62%)> Lancer Gold (50 + 1.8) % SP (67.15%)> Pymetrozine 50% WG (65.48%)> Diafenthiuron 50% WP (63.78%)> Buprofezin 25% SC (63.51%)> Abamectin 1.8% EC (62.49%)> Spinosad 45% SC (60.89%)> Chlorantraniliprole 18.5% SC (56.88%)> Indoxacarb 14.5% SC (53.48%). Similarly, Joost *et al.* (2006) observed that aphids and plant bugs cease their feeding within 15 to 30 minutes upon exposure to Flonicamid and subsequently recorded the death of these insects after some time depending upon the existing environmental conditions. Morita *et al.* (2007) said that the nymphs born from adults when exposed to Flonicamid for 3 hours displayed significantly higher mortality. Koo *et al.* (2014) noted the effects of sublethal exposure to Flonicamid and Imidacloprid and the mechanisms by which these insecticides affect the feeding behaviour of *A.*

gossypii. The lowest net reproductive rate was recorded in *A. gossypii* treated with the LC_{30} of Flonicamid in their result.

Effect of newer insecticides against the population of thrips, *Thrips tabaci* Lindeman, in tomato:First spray:

The thrips population was nearly uniform one day before treatment was imposed. table 4 shows that all insecticidal treatments were much more effective at reducing thrips populations than the untreated control. Pre-treatment thrips populations were uniformly distributed throughout all plots, ranging from 5.60 to 5.80 (average number of thrips) per plant. The thrips population after one day after insecticidal spray varied between 4.47 and 5.53 per plant in different insecticidal treatments, while it was 5.87 per plant in the untreated control. After three and five days after spraying, the decreasing rate of the thrips population remained the same. It ranged from 3.53-4.80 and 1.73-4.00 per plant, respectively, and all the treatments were superior to the control (6.20 and 6.47 per plant, respectively). After seven days of spraying, the mean population of thrips gradually increases, and the same trend is also observed in ten and fifteen days after spraying. At seven, ten, and fifteen days, the mean population of thrips varied from 2.27-4.47, 2.67-4.60, and 3.13-5.40 per plant, respectively, whereas in the untreated plot, this population was varied from 6.73, 7.00 and 7.33 per plant respectively. After fifteen days of first spraying, the overall mean population of thrips in all the treated plots varied between 3.36-4.90 per plant, which is significantly much more superior to the untreated control (6.46 per plant).After the first, third, fifth, seventh, tenth, and fifteenth day of spray, Lancer gold (T_9) was found to be significantly superior over the rest of the treatments, followed by Buprofezin (T_3), Flonicamid (T_8), Pymetrozine (T_7), Diafenthiuron (T_1), Spinosad (T_5), Abamectin (T_2), Chlorantraniliprole (T_6) were found statistically at par with each other in most of the days. Indoxacarb 14.5% SC @ 300 g a.i ha^{-1} was inferior among all insecticidal treatments. Further, the mean per cent reduction in whitefly population over control after first, third, fifth, seventh, tenth and fifteenth days of spray was in descending order: Lancer gold (47.98%) > Buprofezin (42.41%) > Flonicamid(38.85)>Pymetrozine(34.98%)>Diafenthiuron(32.19%)>Spinosad(30.49%)>Abamectin(29.72%) > Chlorantraniliprole(26.78%)> Indoxacarb (24.14%).

Second spray:

The thrips population was nearly uniform one day before treatment was imposed. table 4 shows that all insecticidal treatments were much more effective at reducing thrips populations than the untreated control. Pre-treatment thrips populations ranged from 3.13 to 7.33 (average number of thrips) per plant. After one day after insecticidal spray, the population of thrips varied between 2.60 and 4.87 per plant in different insecticidal treatments, while it was 7.40 thrips per plant in the untreated control. After three and five days after spraying, the decreasing rate of the thrips population remained the same. It ranged from 2.07-4.20 and 1.27-3.80 per plant, respectively, and all the treatments were superior to the control (7.00 and 6.53 per plant, respectively). The decreasing trend of the thrips population was also observed on seven, ten, and fifteen days after spraying. At seven, ten, and fifteen days, the mean population of thrips varied from 0.73-3.40, 0.40-3.00, and 0.27-2.87 per plant, respectively, whereas in the untreated plot, this population was varied from 5.53, 4.93 and 4.33 per plant respectively. After fifteen days of first spraying, the overall mean population of thrips in all the treated plots varied between 1.50-3.93 per plant, which was significantly much more superior to the untreated control (6.15 per plant).After the first, third, fifth, seventh, tenth, and fifteenth day of spray, Lancer gold (T_9) was found to be significantly superior over the rest of the treatments. Indoxacarb 14.5% SC @ 300 g a.i ha^{-1} was inferior among all the insecticidal treatments. Further, the mean per cent reduction in whitefly population over control after first, third, fifth, seventh, tenth and fifteenth days of spray was in descending order: Lancer gold (75.60%)>Buprofezin(68.45%)>Flonicamid(65.69) > Pymetrozine (61.30%)> Diafenthiuron (53.98%)> Spinosad(51.54%)>Abamectin(45.36%)> hlorantraniliprole (43.25%)>Indoxacarb(36.09%). These results show similarity with previous works like, Vikas *et al.* (2005) reported, the green chilli yield was highest from the plots applied with imidacloprid and gave significantly higher green chilli yield than the other insecticides. Dey *et al.* (2005) also stated that Imidacloprid 70 WS successfully controlled the initial sucking pest complex of okra when applied as a seed treatment.

Table 3: Effect of newer molecules of insecticides against the population of aphid, *Aphis gossypii* Glover in tomato after first and second application during 2019-20

Treat. No.	Treatments	Dose (g a.i. ha^{-1})	First spray									Second spray								
			Mean population of aphid per plant*							Post-treatment mean	MRC (%)	Mean population of aphid per plant*							Post-treatment mean	MRC (%)
			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS		
T_1	Diafenthiuron	300	20.47 (4.63)	16.27 (5.15)	12.07 (3.61)	6.87 (2.80)	13.40 (3.79)	16.87 (4.22)	20.40 (4.62)	15.19	57.49	20.40 (4.62)	18.47 (4.41)	14.67 (3.95)	8.87 (3.14)	6.27 (2.69)	4.27 (2.29)	1.60 (1.60)	10.65	63.78
T_2	Abamectin	10	20.13 (4.59)	17.20 (4.26)	13.60 (3.82)	7.33 (2.88)	13.93 (3.86)	18.13 (4.37)	19.73 (4.55)	15.72	56.01	19.73 (4.55)	18.80 (4.45)	15.00 (4.00)	9.40 (3.22)	7.07 (2.83)	4.80 (2.40)	2.40 (1.83)	11.03	62.49
T_3	Buprofezin	250	20.33 (4.61)	16.67 (4.20)	13.27 (3.77)	6.93 (2.81)	13.60 (3.82)	17.87 (4.34)	18.93 (4.46)	15.37	56.99	18.93 (4.46)	18.60 (4.42)	14.80 (3.97)	9.27 (3.20)	6.80 (2.78)	4.53 (2.35)	2.20 (1.78)	10.73	63.51
T_4	Indoxacarb	300	20.33 (4.61)	18.87 (4.45)	17.33 (4.28)	15.13 (4.01)	16.33 (4.16)	19.47 (4.52)	22.07 (4.80)	18.50	48.23	22.07 (4.80)	20.73 (4.66)	17.20 (4.26)	13.40 (3.79)	10.13 (3.33)	7.73 (2.95)	4.47 (2.33)	13.68	53.48
T_5	Spinosad	73	20.53 (4.64)	17.67 (4.32)	13.93 (3.86)	8.67 (3.12)	14.27 (3.90)	18.80 (4.45)	20.13 (4.59)	16.29	54.42	20.13 (4.59)	18.87 (4.45)	16.00 (4.12)	10.07 (3.32)	7.47 (2.90)	5.13 (2.47)	2.80 (1.94)	11.50	60.89
T_6	Clorantraniliprole	30	21.93 (4.78)	18.20 (4.38)	14.27 (3.90)	8.73 (3.11)	15.73 (4.09)	19.00 (4.47)	21.60 (4.75)	17.07	52.23	21.60 (4.75)	20.73 (4.66)	16.73 (4.21)	11.93 (3.59)	8.47 (3.07)	5.93 (2.63)	3.33 (2.07)	12.68	56.88
T_7	Pymetrozine	200	19.80 (4.56)	16.33 (4.16)	10.13 (3.33)	6.40 (2.71)	10.53 (3.39)	16.00 (4.12)	18.80 (4.45)	14.00	60.82	18.80 (4.45)	18.20 (4.38)	14.40 (3.92)	8.13 (3.01)	5.93 (2.62)	4.07 (2.25)	1.53 (1.59)	10.15	65.48
T_8	Flonicamid	60	20.27 (4.60)	15.53 (4.06)	9.53 (3.24)	4.93 (2.43)	9.93 (3.30)	14.73 (3.96)	17.33 (4.28)	13.18	63.12	17.33 (4.28)	16.53 (4.18)	11.00 (3.46)	7.47 (2.90)	4.87 (2.42)	2.47 (1.86)	0.80 (1.33)	8.64	70.62
T_9	Lancer gold	518	21.00 (4.69)	16.27 (4.15)	9.87 (3.29)	5.93 (2.63)	10.27 (3.35)	15.67 (4.08)	18.07 (4.36)	13.87	61.19	18.07 (4.36)	17.73 (4.32)	13.53 (3.81)	8.07 (3.01)	5.47 (2.54)	3.60 (2.14)	1.13 (1.45)	9.66	67.15
T_{10}	Control	-	20.07 (4.58)	28.27 (5.40)	33.13 (5.83)	37.73 (6.220	41.80 (6.53)	43.87 (6.69)	45.33 (6.80)	35.74	-	45.33 (6.80)	41.13 (6.48)	37.20 (6.17)	29.07 (5.47)	22.60 (4.84)	18.07 (4.36)	12.47 (3.66)	29.41	-
SEm±			0.054	0.044	0.052	0.068	0.087	0.076	0.071			0.071	0.076	0.085	0.078	0.104	0.074	0.101		
CD @ 5%			NS	0.132	0.154	0.204	0.261	0.227	0.212			0.212	0.226	0.254	0.235	0.311	0.221	0.303		

Table 4: Effect of newer molecules of insecticides against the population of thrips, *Thrips tabaci* Lindeman in tomato after first and second application during 2019-20

Treat. No.	Treatments	Dose (g a.i. ha^{-1})	First spray									Second spray								
			Mean population of thrips per plant*							Post-treatment mean	MRC (%)	Mean population of thrips per plant*							Post-treatment mean	MRC (%)
			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS		
T_1	Diafenthiuron	300	5.80 (2.60)	5.33 (2.51)	4.33 (2.30)	3.13 (2.03)	3.47 (2.11)	3.93 (2.22)	4.67 (2.38)	4.38	32.19	4.67 (2.38)	4.00 (2.23)	3.27 (2.06)	2.93 (1.98)	2.07 (1.74)	1.60 (1.60)	1.27 (1.49)	2.83	53.98
T_2	Abamectin	10	5.47 (2.54)	5.27 (2.50)	4.47 (2.33)	3.40 (2.09)	3.87 (2.20)	4.27 (2.29)	5.07 (2.46)	4.54	29.72	5.07 (2.46)	4.60 (2.36)	3.73 (2.16)	3.27 (2.05)	2.73 (1.92)	2.27 (1.79)	1.87 (1.68)	3.36	45.36
T_3	Buprofezin	250	5.67 (2.58)	4.67 (2.37)	3.67 (2.15)	2.27 (1.80)	2.87 (1.96)	3.33 (2.08)	3.60 (2.14)	3.72	42.41	3.60 (2.14)	3.13 (2.03)	2.53 (1.87)	1.73 (1.65)	1.20 (1.48)	0.80 (1.34)	0.60 (1.26)	1.94	68.45
T_4	Indoxacarb	300	5.67 (2.58)	5.33 (2.51)	4.80 (2.40)	4.00 (2.23)	4.47 (2.33)	4.60 (2.36)	5.40 (2.52)	4.90	24.14	5.40 (2.52)	4.87 (2.42)	4.20 (2.27)	3.80 (2.19)	3.40 (2.09)	3.00 (2.00)	2.87 (1.96)	3.93	36.09
T_5	Spinosad	73	5.80 (2.60)	5.33 (2.51)	4.53 (2.35)	3.40 (2.09)	3.67 (2.15)	4.00 (2.23)	4.67 (2.37)	4.49	30.49	4.67 (2.37)	4.13 (2.64)	3.27 (2.06)	2.93 (1.98)	2.40 (1.84)	1.93 (1.70)	1.53 (1.59)	2.98	51.54
T_6	Clorantraniliprole	30	5.73 (2.59)	5.53 (2.55)	4.80 (2.4)	3.67 (2.15)	4.07 (2.25)	4.33 (2.30)	5.00 (2.44)	4.73	26.78	5.00 (2.44)	4.60 (2.36)	3.93 (2.22)	3.47 (2.11)	2.87 (1.96)	2.33 (1.82)	2.20 (1.78)	3.49	43.25
T_7	Pymetrozine	200	5.60 (2.56)	5.13 (2.47)	4.20 (2.27)	2.80 (1.94)	3.40 (2.09)	3.93 (2.22)	4.33 (2.30)	4.20	34.98	4.33 (2.30)	3.47 (2.10)	2.87 (1.96)	2.13 (1.76)	1.67 (1.62)	1.20 (1.47)	1.00 (1.40)	2.38	61.30
T_8	Flonicamid	60	5.73 (2.59)	4.93 (2.43)	3.93 (2.22)	2.47 (1.85)	3.07 (2.01)	3.60 (2.14)	3.93 (2.22)	3.95	38.85	3.93 (2.22)	3.27 (2.06)	2.53 (1.87)	1.87 (1.68)	1.40 (1.54)	1.00 (1.41)	0.80 (1.34)	2.11	65.69
T_9	Lancer gold	518	5.73 (2.59)	4.47 (2.33)	3.53 (2.12)	1.73 (1.65)	2.27 (1.80)	2.67 (1.91)	3.13 (2.03)	3.36	47.98	3.13 (2.03)	2.60 (1.89)	2.07 (1.75)	1.27 (1.50)	0.73 (1.31)	0.40 (1.18)	0.27 (1.12)	1.50	75.60
T_{10}	Control	-	5.60 (2.56)	5.87 (2.62)	6.20 (2.68)	6.47 (2.73)	6.73 (2.78)	7.00 (2.82)	7.33 (2.88)	6.46	-	7.33 (2.88)	7.40 (2.89)	7.00 (2.82)	6.53 (2.74)	5.53 (2.55)	4.93 (2.43)	4.33 (2.30)	6.15	-
SEm±			0.039	0.028	0.051	0.058	0.056	0.046	0.047			0.047	0.059	0.072	0.081	0.084	0.078	0.074		
CD @ 5%			NS	0.085	0.152	0.174	0.168	0.138	0.142			0.142	0.176	0.215	0.241	0.252	0.233	0.223		

Table 5: Effect of newer molecules of insecticides against the population of spiders in tomato after first and second application during 2019-20

Treat. No.	Treatments	Dose (g a.i. ha^{-1})	First spray									Second spray								
			Mean population of spiders per plant*							Post-treatment mean	MRC (%)	Mean population of spiders per plant*							Post-treatment mean	MRC (%)
			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS		
T_1	**Diafenthiuron**	300	4.00 (2.22)	3.53 (2.12)	2.80 (1.94)	3.13 (2.02)	3.60 (2.13)	3.80 (2.18)	4.47 (2.33)	3.62	4.00 (2.22)	4.47 (2.33)	3.93 (2.21)	3.60 (2.13)	3.20 (2.03)	2.87 (1.95)	2.40 (1.83)	2.00 (1.71)	3.21	4.47 (2.33)
T_2	**Abamectin**	10	3.93 (2.22)	3.40 (2.09)	2.73 (1.92)	3.07 (2.01)	3.27 (2.06)	3.53 (2.12)	4.00 (2.23)	3.42	3.93 (2.22)	4.00 (2.23)	3.73 (2.17)	3.13 (2.03)	2.87 (1.96)	2.53 (1.88)	2.40 (1.84)	1.73 (1.65)	2.91	4.00 (2.23)
T_3	**Buprofezin**	250	3.80 (2.17)	3.53 (2.11)	3.07 (1.99)	3.27 (2.04)	3.60 (2.13)	3.87 (2.18)	4.67 (2.36)	3.69	3.80 (2.17)	4.67 (2.36)	4.33 (2.29)	3.87 (2.18)	3.87 (2.19)	3.20 (2.03)	2.93 (1.97)	2.67 (1.90)	3.65	4.67 (2.36)
T_4	**Indoxacarb**	300	3.47 (2.19)	2.07 (1.75)	1.93 (1.71)	2.53 (2.87)	2.87 (1.96)	3.47 (2.11)	3.93 (2.22)	2.90	3.47 (2.19)	3.93 (2.22)	2.93 (1.97)	2.13 (2.70)	1.73 (1.65)	1.60 (1.61)	1.33 (1.52)	0.87 (1.36)	2.08	3.93 (2.22)
T_5	**Spinosad**	73	3.80 (2.17)	3.40 (2.08)	2.93 (1.97)	3.13 (2.02)	3.47 (2.10)	3.87 (2.19)	4.40 (2.31)	3.57	3.80 (2.17)	4.40 (2.31)	3.73 (2.17)	3.13 (2.02)	2.60 (1.89)	2.13 (1.76)	1.73 (1.64)	1.47 (1.56)	2.74	4.40 (2.31)
T_6	**Clorantraniliprole**	30	3.73 (2.17)	3.20 (2.04)	2.53 (1.87)	2.80 (1.94)	3.07 (2.01)	3.40 (2.09)	4.13 (2.26)	3.27	3.73 (2.17)	4.13 (2.26)	3.27 (2.06)	2.40 (1.83)	2.13 (1.76)	1.80 (1.67)	1.73 (1.65)	1.27 (1.50)	2.39	4.13 (2.26)
T_7	**Pymetrozine**	200	3.87 (2.19)	3.53 (2.12)	2.93 (1.97)	3.07 (2.00)	3.60 (2.13)	3.80 (2.18)	4.67 (2.37)	3.64	3.87 (2.19)	4.67 (2.37)	4.07 (2.24)	3.60 (2.14)	3.27 (2.05)	2.93 (1.97)	2.60 (1.89)	2.27 (1.79)	3.34	4.67 (2.37)
T_8	**Flonicamid**	60	3.93 (2.22)	3.73 (2.17)	3.67 (2.15)	3.67 (2.15)	4.07 (2.25)	4.60 (2.36)	4.93 (2.43)	4.09	3.93 (2.22)	4.93 (2.43)	4.27 (2.29)	4.07 (2.25)	3.87 (2.20)	3.60 (2.14)	3.47 (2.11)	3.40 (2.09)	3.94	4.93 (2.43)
T_9	**Lancer gold**	518	4.07 (2.24)	3.80 (2.19)	3.47 (2.11)	3.67 (2.16)	3.93 (2.22)	4.13 (2.26)	4.47 (2.33)	3.93	4.07 (2.24)	4.47 (2.33)	4.33 (2.30)	3.93 (2.22)	3.67 (2.15)	3.40 (2.09)	3.33 (2.08)	3.07 (2.01)	3.74	4.47 (2.33)
T_{10}	**Control**	-	3.73 (2.17)	5.27 (2.50)	5.47 (2.54)	5.60 (2.56)	5.67 (2.58)	6.00 (2.64)	6.60 (2.75)	5.48	3.73 (2.17)	6.60 (2.75)	6.67 (2.76)	6.47 (2.73)	5.87 (2.61)	5.20 (2.48)	4.60 (2.36)	4.27 (2.29)	5.67	6.60 (2.75)
SEm±			0.124	0.111	0.12	0.110	0.104	0.104	0.096			0.096	0.097	0.102	0.097	0.099	0.092	0.081		
CD @ 5%			NS	0.333	0.361	0.329	0.312	0.310	0.286			0.286	0.290	0.307	0.291	0.295	0.275	0.242		

Table 6: Effect of newer molecules of insecticides against the population of coccinellids in tomato after first and second application during 2019-20

Treat. No.	Treatments	Dose (g a.i. ha^{-1})	First spray									Second spray								
			Mean population of coccinellids per plant*							Post-treatment mean	MRC (%)	Mean population of coccinellids per plant*							Post-treatment mean	MRC (%)
			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS			PTC	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS		
T_1	**Diafenthiuron**	300	2.93 (1.98)	2.53 (1.87)	2.20 (1.78)	2.27 (1.80)	2.47 (1.86)	2.87 (1.96)	3.33 (2.08)	2.08	2.93 (1.98)	3.33 (2.08)	2.67 (1.91)	2.33 (1.82)	2.27 (1.80)	2.00 (1.73)	1.80 (1.67)	1.60 (1.61)	2.29	3.33 (2.08)
T_2	**Abamectin**	10	2.87 (1.96)	2.20 (1.78)	1.73 (1.65)	2.07 (1.75)	2.33 (1.82)	2.53 (1.87)	3.00 (1.99)	1.99	2.87 (1.96)	3.00 (1.99)	2.53 (1.87)	2.13 (1.76)	1.80 (1.67)	1.53 (1.59)	1.47 (1.57)	1.33 (1.52)	1.97	3.00 (1.99)
T_3	**Buprofezin**	250	3.80 (2.17)	2.87 (1.94)	2.53 (1.85)	2.40 (1.82)	2.67 (1.90)	3.13 (2.02)	3.87 (2.20)	2.20	3.80 (2.17)	3.87 (2.20)	3.13 (2.03)	2.73 (1.93)	2.47 (1.86)	2.27 (1.80)	2.07 (1.75)	1.87 (1.69)	2.63	3.87 (2.20)
T_4	**Indoxacarb**	300	2.93 (1.98)	1.87 (1.69)	1.47 (1.56)	1.60 (1.61)	1.67 (1.63)	1.73 (1.65)	2.13 (1.76)	1.76	2.93 (1.98)	2.13 (1.76)	1.67 (1.63)	1.33 (1.52)	1.27 (1.50)	1.07 (1.43)	1.00 (1.41)	0.93 (1.38)	1.34	2.13 (1.76)
T_5	**Spinosad**	73	3.00 (2.00)	2.00 (1.72)	1.67 (1.62)	1.93 (1.70)	2.27 (1.80)	2.53 (1.87)	3.00 (1.99)	1.99	3.00 (2.00)	3.00 (1.99)	2.33 (1.82)	1.93 (1.70)	1.67 (1.63)	1.53 (1.59)	1.40 (1.54)	1.13 (1.45)	1.86	3.00 (1.99)
T_6	**Clorantraniliprole**	30	2.80 (1.94)	1.93 (1.71)	1.60 (1.60)	1.67 (1.62)	1.93 (1.71)	2.20 (1.78)	2.60 (1.89)	1.89	2.80 (1.94)	2.60 (1.89)	2.00 (1.72)	1.67 (1.62)	1.47 (1.56)	1.33 (1.52)	1.20 (1.48)	1.13 (1.45)	1.63	2.60 (1.89)
T_7	**Pymetrozine**	200	2.80 (1.94)	2.53 (1.87)	2.20 (1.78)	2.27 (1.80)	2.53 (1.87)	3.00 (1.99)	3.53 (2.12)	2.12	2.80 (1.94)	3.53 (2.12)	2.87 (1.96)	2.47 (1.85)	2.27 (1.80)	2.07 (1.73)	2.00 (1.71)	1.93 (1.69)	2.45	3.53 (2.12)
T_8	**Flonicamid**	60	3.07 (2.01)	2.93 (1.97)	2.60 (1.89)	2.53 (1.87)	3.13 (2.03)	3.73 (2.17)	4.20 (2.27)	2.27	3.07 (2.01)	4.20 (2.27)	3.40 (2.09)	3.00 (1.99)	2.93 (1.97)	2.73 (1.92)	2.47 (1.85)	2.33 (1.82)	3.00	4.20 (2.27)
T_9	**Lancer gold**	518	3.27 (2.06)	2.87 (1.69)	2.60 (1.89)	2.47 (1.85)	2.73 (1.92)	3.13 (2.03)	3.93 (2.21)	2.21	3.27 (2.06)	3.93 (2.21)	3.20 (2.04)	2.87 (1.96)	2.73 (1.92)	2.53 (1.87)	2.40 (1.83)	2.20 (1.78)	2.84	3.93 (2.21)
T_{10}	**Control**	-	3.47 (2.10)	3.73 (2.17)	4.00 (2.23)	4.20 (2.27)	4.40 (2.32)	4.60 (2.36)	4.87 (2.42)	4.18	3.47 (2.10)	4.87 (2.42)	5.00 (2.44)	4.60 (2.36)	4.33 (2.30)	4.00 (2.23)	3.80 (2.19)	3.67 (2.16)	4.32	4.87 (2.42)
SEm±			0.097	0.095	0.103	0.102	0.082	0.08	0.083			0.083	0.078	0.078	0.070	0.075	0.069	0.073		
CD @ 5%			NS	0.284	0.308	0.305	0.246	0.238	0.249			0.249	0.235	0.235	0.210	0.224	0.208	0.219		

Impact of insecticides on the natural enemies present in tomato fields:

Effect of newer insecticides on the population of spiders:

The average number of spiders per plant was observed one day before the 1st spray, which non-significantly varied from 3.73 to 4.07 spiders per plant (table 5). The highest spider population (overall mean value) (irrespective of DAS) was observed in Flonicamid (4.09 spiders per plant), followed by Lancer Gold (3.39 spiders per plant), Buprofezin (3.69 spiders per plant), Pymetrozine (3.64 spiders per plant), Diafenthiuron (3.62 spiders per plant), Abamectin (3.42 spiders per plant), Spinosad (3.57 spiders per plant), Chlorantraniliprole (3.27 spiders per plant) and Indoxacarb (2.90 spiders per plant). Thus, data on the mortality of these predators showed a slight decrease in the spider population in all insecticide-treated plots than the untreated plots (5.48 spiders per plant), which are more or less at par with each other. A more or less similar trend of insecticidal effect was also observed at 2nd spray (table 5), where the highest mean population of spiders was found in Flonicamid (3.94 spiders per plant), followed by Lancer Gold (3.74 spiders per plant), Buprofezin (3.65 spiders per plant), Pymetrozine (3.34 spiders per plant), Diafenthiuron (3.21 spiders per plant), Abamectin (2.91 spiders per plant), Spinosad (2.74 spiders per plant), Chlorantraniliprole (2.39 spiders per plant) and Indoxacarb (2.08 spiders per plant).

Effect of newer insecticides on the population of coccinellids:

The average number of spiders per plant was observed one day before the 1st spray, which non-significantly varied from 2.80 to 3.80 coccinellids per plant (table 6). The highest spider population (overall mean value) (irrespective of DAS) was observed in Flonicamid (2.27 coccinellids per plant), followed by Lancer Gold (2.21 coccinellids per plant), Buprofezin (2.20 coccinellids per plant), Pymetrozine (2.12 coccinellids per plant), Diafenthiuron (2.08 coccinellids per plant), Abamectin (1.99 coccinellids per plant), Spinosad (1.99 coccinellids per plant), Chlorantraniliprole (1.89 spiders per plant) and Indoxacarb (1.76 spiders per plant). Thus, data on the mortality of these predators showed a slight decrease in the spider population in all insecticide-treated plots than the untreated plots (4.18 spiders per plant), which are more or less at par with each other. A more or less similar trend of insecticidal effect was also observed at 2nd spray, where the highest mean population of spiders was found in Flonicamid (3.00 coccinellids per plant), followed by Lancer Gold (2.84 coccinellids per plant), Buprofezin (2.63 coccinellids per plant), Pymetrozine (2.45 coccinellids per plant), Diafenthiuron (2.29 coccinellids per plant), Abamectin (1.97 coccinellids per plant), Spinosad (1.86 coccinellids per plant), Chlorantraniliprole (1.63 spiders per plant) and Indoxacarb (1.34 spiders per plant) (table 6).Thus, based on the overall mean of the natural enemies' population after 1st and 2nd spray during the investigation, Flonicamid 50% WG and Lancer Gold (50 + 1.8) % SP appeared to be the safest treatment for the spider. In contrast, Indoxacarb 14.5% SC and Chlorantraniliprole 18.5% SC produced significantly higher mortality among all of the treatments. These findings nearly agree with the previous report of Morita *et al.* (2000) who also observed Flonicamid with a very favourable toxicological, environmental, and ecotoxic profile and showed no foremost negative impact on beneficial insects and mites such as *Bombyx mori*, *Apis mellifera*, *Harmonia axyridis*, and *Phytoseiulus persimilis.*

Conclusion

Among the numerous insect pests attacking tomato from transplanting to harvesting, the sucking pests are the prime reason for reducing the fruit yield directly by feeding and indirectly transmitting the notorious plant diseases. To conclude, we can say that the findings indicate all the pesticide treatments including plant products, were more successful than the control in lowering sucking-pest populations. Lancer Gold (50 + 1.8) % SP was highly effective in controlling the whitefly and thrips population, while Flonicamid 50% WG was found to be of more effective on the aphid population than all other treatments on tomato. In case of natural enemies also, these two insecticides were found to be the safest among all. Due to various target sites, high selective toxicity towards insects, stimulation of the mechanisms of plant self-defence, and lack of cross-resistance, these two insecticides may effectively be included in the IPM strategies of tomato sucking pest complex.

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Conflict of interest

The authors declare that they have no conflict of interest.

References

Abdel-Baky, N. F., & Al-Deghairi, M. A. (2008). Role of host plants on the biological aspects and parasitism levels of *Eretmocerus mundus* Mercet (Hymenoptera: Aphelinidae), a parasitoid of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae). *Journal of Entomology*, 5 (6), 356-368.

Cahill, M., Jarvis, W., Gorman, K., & Denholm, I. (1996). Resolution of baseline responses and documentation of resistance to buprofezin in *Bemisia tabaci* (Homoptera: Aleyrodidae). *Bulletin of Entomological Research*, 86 (2), 117-122.

Dey, P. K., Jana, S. K., Chakraborty, G., & Somchoudhury, A. K. (2005). Evaluation of Imidacloprid (70 WS and 20 SL) against sucking pest complex of okra, *Abelmoschus esculentus*. *Journal of Entomological Research*, 29 (3), 215-218.

Dhar, T., & Bhattacharya, S. (2015). Efficacy of imidacloprid and Spinosad against pest complex of okra and tomato. *International journal of bioresource, environment and agricultural sciences,* 1 (3), 126-131.

Dikshit, A. K., Lal, O. P., & Srivastava, Y. N. (2000). Persistence of Pyrethroid and Nicotiriyl Insecticides on Okra Fruits. *Pesticide Research Journal*, 12 (2), 227-231.

Hancock, H. G., de Lourdes Fustaino, F. M., & Morita, M. (2003). Flonicamid (F1785, IKI220): novel insecticide chemistry for cotton and other crops. *Proceedings of Beltwide Cotton Conferences,* 2, 83-88.

Joost, H., Staetz, C., Black, B., Hayashi, J., Kinne, L., Kelly, G., & Treacy, K. (2006). Flonicamid: a novel mode of action for piercing and sucking insects. In *Proceedings, Beltwide Cotton Conferences, National Cotton Council, Memphis, TN* (pp: 1583-1590).

Kar, A. (2017). Bioefficacy evaluation of imidacloprid 17.8% SL and thiamethoxam against whitefly on tomato and their effect on natural enemies. *Journal of Entomology and Zoology Studies*, 5 (3), 1064- 1067.

Khan, J. A., & Ahmad, J. (2005). Diagnosis, monitoring and transmission characteristics of Cotton leaf curl virus. *Current Science*, 1803-1809.

Koo, H. N., Lee, S. W., Yun, S. H., Kim, H. K., & Kim, G. H. (2015). Feeding response of the cotton aphid, *Aphis gossypii*, to sublethal rates of flonicamid and imidacloprid. *Entomologia Experimentalis et Applicata*, 154 (2), 110-119.

Kramer, W., Schirmer, U., Jeschke, P., & Witschel, M. (2012). *Modern Crop Protection Compounds* (second edition) Vol. 3, Wiley-VCH, Weinheim, Germany.

Morita, M., Ueda, T., Yoneda, T., Koyanagi, T., & Haga, T. (2007). Flonicamid, a novel insecticide with a rapid inhibitory effect on aphid feeding. *Pest Management Science: formerly Pesticide Science*, 63 (10), 969-973.

Morita, M., Ueda, T., Yoneda, T., Koyanagi, T., Murai, S., Matsuo, N., ... & Ruelens, P. (2000). IKI-220-a novel systemic aphicide. In *The BCPC Conference: Pests and diseases, Volume 1. Proceedings of an international conference held at the Brighton Hilton Metropole Hotel, Brighton, UK, 13-16 November 2000*, 2, 59-65.

Seal, D. R., Betancourt, R., & Sabines, C. M. (2002). Control of *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) using various insecticides. In *Proceedings of the Florida State Horticultural Society,*115, 308-314.

Sridhar, V., Chakravarthy, A. K., Asokan, R., Vinesh, L. S., Rebijith, K. B., & Vennila, S. (2014). New record of the invasive South American tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in India. *Pest Management in Horticultural Ecosystems*, 20 (2), 148-154.

Vikas, S., Thakur, B. S., & Chandraker, M. K. (2005). Bio-efficacy of insecticides against insect pests of chilli. *Environment and Ecology,* 3, 600-604.

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