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Relative toxicity of selected insecticides against adult whitefly, *T. vaporariorum* in potted condition

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Abstract
The present experiment was conducted to assess relative toxicity of selected insecticides against whitefly in the Entomology laboratory at College of Horticulture, Mudigere during the year 2014-2015. Among the eleven treatments, imidachloprid, thiamethoxam and cyantraniliprole were highly toxic to adults which recorded 100 per cent mortality, four days after treatment. Cyantraniliprole recorded the highest adult mortality comparatively early than imidachloprid and thiamethoxam. Fipronil 80% WG, recorded 100 percent mortality five days after treatment which was followed by emamectin benzoate 5% SG at sixth day after treatment and recorded as next best treatments under laboratory condition against whitefly. Acephate 75% SP and azadirhactin 10000 ppm recorded highest level of mortality (100%) at seventh and eighth day after treatment, respectively which was followed by triazophos 40% EC, spinosad 480% SC and buprofezin 25% SC at eleventh day after treatment. Considering the result, cyantraniliprole, thiamethoxam and imidacloprid were recommended for effective control of sucking pests in cotton ecosystem.

Keywords: Whitefly, *Trialeurodes vaporariorum*, Insecticides, Relative toxicity, Mortality

1. Introduction
Solanaceous crops are important group of warm season vegetables consumed all over the world and grown in tropical and subtropical regions [17]. Among that, tomato (*Solanum lycopersicum* L.) is one of the most popular vegetable grown all over the world. In India, tomato has wider coverage in comparison to other vegetables with an area of 5.60 lakh hectares and production of 8.08 lakh metric tonnes [18]. In nature tomato plant is attacked by a number of insects, mites and other non-insect pests, which reduce yield and spoil the quality of tomato fruits. Among these *T. vaporariorum*, a sap feeder reported to be infesting approximately 859 host plant species, belonging to 469 genera in 121 families has attained a major pest status globally [1]. *Trialeurodes vaporariorum* cause damage in three ways *viz.*, the vitality of the plants is lowered through the loss of cell sap; normal photosynthesis is interfered due to the growth of sooty mould on the honey dew and transmits a number of viruses [8]. Thus, it not only sucks the plant sap while feeding, but also transmits a limited number of Crinivirus and Torradovirus. The criniviruses cause Tomato Infectious Chlorosis Virus (TICV) and Tomato Chlorosis Virus (ToCV) in tomato [20, 9, 3, 4].
Although, several management strategies are available to suppress the pests on crops, efficacy, spread and cost of operations are not satisfactory in comparison with chemical control measures. Insecticides have lead to development of resurgence and resistance in insects and also increased the cost of plant protection materials. Any delay in application of pesticides in tomato ecosystem results in heavy crop losses [14]. The use of insecticides is the primary strategy employed to control whiteflies, *T. vaporariorum* in tomato. This has been particularly evident during the past decade where whiteflies have shown the potential to cause millions of dollars in crop damage and lost yields [11].
Considering the heavy loss by this pest, a number of insecticides have been recommended for its effective control. This pest attains exponential number within a short time and needs repeated application of insecticides for successful cultivation of tomato [14]. Several new classes of insecticide chemistry *viz.*, neonicotinoids, insect growth regulators and new diamide group have been developed recently that effectively control whitefly population. All of these compounds have selective activity against whitefly nymphal stages, but have limited activity

against adults. Due to resistance of whitefly against older insecticides, there is a need to identify effective and safer new insecticides for management of whiteflies in tomato. Considering this, the present study was conducted to test the efficacy of insecticides against adult whitefly under laboratory conditions and also to know the time interval at how many days after treatment of insecticides would give 100 per cent adult mortality.

2. Materials and Methods

The experiment was conducted in the Entomology laboratory at College of Horticulture, Mudigere, Chikkamagaluru taluk during early summer (March) of 2014-15.

2.1 Maintenance of whitefly culture

Different stages of whitefly populations were collected from infested tomato fields and reared on tomato plants grown in pots inside the rearing cages in the laboratory. After the establishment of culture, these pots were shifted to the whitefly rearing house with (polythene roof) to get constant supply of whiteflies for conducting further experiments. The adult whiteflies resting over infested leaves were blown off and sufficient number of whitefly nymphs and puparia (pseudo pupae) along with the tomato leaves was shifted to the laboratory and maintained in plastic boxes with mesh lid for emergence of new, uniform aged adults.

On the other side, the tomato plants (hybrid, NS 50) were raised in pots under 40 mesh net house to avoid the pest attack of any. In every pot, only one tomato plant was grown and four plants each were maintained for eleven treatments in order to get sufficient supply of treated leaves. These tomato plants were sprayed with the selected insecticides at recommended dosage (Table 1). Top three leaves from treated tomato plants were brought to the laboratory and maintained in separate plastic boxes. The newly emerged adult whiteflies were collected from the plastic boxes used for obtaining new, uniform aged adults with the help of aspirator and released in to the plastic boxes having treated tomato leaves in a batch of 30 adults. This was replicated thrice.

The treated leaves used and the whiteflies released on these treated leaves was for a single time. The observation on adult mortality was recorded at an interval of every 24 hours up to 100 per cent mortality in all the treatments.

2.2 Statistical analysis

The data thus obtained through experiments was subjected to Completely Randamised Design ANOVA test for analysis to determine the relative toxicity of selected insecticides against adult whitefly, *T. vaporariorum*. The mortality in untreated control would affect the precision of the result. In order to overcome this error, a correction was applied by using the Abbott's formula given as under

$$P = \frac{T - C}{100 - C} \times 100$$

Where,

P = the corrected percent mortality

T = the observed per cent mortality in treatment

C = the per cent mortality in control.

The data on corrected percent mortality obtained were used for comparison of different treatments from third day after treatment onwards up to eleventh day after treatment.

3. Results

There was a significant difference among the treatments with respect to adult mortality at one day after treatment. Among the treatments, Cyantraniliprole (20.77%) recorded the highest mortality rate which was significantly differed from all other treatments except thiamethoxam (20.03%). Lower per cent mortality was observed in Imidachloprid (15.70%) which was on par with Buprofezin (15.23%), Triazophos (13.03%) and Azadirhactin (10.40%). However, untreated control (T_{11}) recorded zero per cent mortality (Table 1). At two days after treatment, Imidachloprid (43.03%) recorded highest mortality which significantly differed from all other treatments and was on par with Cyantraniliprole (40.03%) and Thiamethoxam (37.83%). A lower mortality rate was observed in Acephate (24.30%) and was on par with Spinosad (23.87%), Azadirhactin (21.63%) and Triazophos (20.03%). However, in untreated control (T_{11}) zero per cent mortality was recorded (Table 1).

At three days after treatment, Cyantraniliprole (96.79%) recorded highest mortality rate which was significantly different from all other treatments and on par with Imidachloprid (84.12%) and Thiamethoxam (82.29%). A lower mortality rate was observed in Fipronil (64.7%) and Acephate (46.96%) and was lesser in treatments Emamectin benzoate (37.88%) followed by Spinosad (24.09 per%) (Table 2). At four days after treatment, Imidachloprid, Thiamethoxam and Cyantraniliprole (100%) recorded cent per cent mortality of adults, respectively. Fipronil (84.00%) recorded as next best treatment which was on par with Acephate (67.61%) and Emamectin benzoate (61.43%). A lower mortality rate was recorded in Spinosad (35.19%) and it was on par with Triazophos (32.47%) and Azadirhactin (25.93%). The least mortality was recorded in Buprofezin (T_{10}) with per cent mortality of 23.99 (Table 2).

Table 1: Relative toxicity of selected insecticides against adult whiteflies (1-2 days)

Treatment no.	Treatment details	Dosage / l.	Number of adults released	1DAT		2DAT	
				Per cent mortality	Corrected percent mortality	Per cent mortality	Corrected percent mortality
T1	Imidachloprid 17.8%SL	0.3 ml	30	15.70 (23.34)	15.70	43.03 (40.97)	43.03
T2	Triazophos 40% EC	2.0 ml	30	13.03 (21.13)	13.03	20.03 (26.57)	20.03
T3	Thiamethoxam 25%WG	0.3 g	30	20.03 (26.57)	20.03	37.83 (37.94)	37.83
T4	Acephate 75% SP	1.0 g	30	6.30 (14.18)	6.30	24.30 (29.53)	24.30
T5	Cyantraniliprole 10% OD	1.8 ml	30	20.77 (27.11)	20.77	40.03 (39.23)	40.03

T6	Azadirhactin 10000 ppm	2.0 ml	30	10.40 (18.81)	10.40	21.63 (27.69)	21.63
T7	Fipronil 80% WG	0.5 g	30	6.60 (14.89)	6.60	17.97 (25.03)	17.97
T8	Emamectin benzoate 5% SG	0.2 g	30	6.37 (14.65)	6.37	17.57 (24.78)	17.57
T9	Spinosad 480% SC	0.2 ml	30	15.23 (22.97)	15.23	23.87 (29.25)	23.87
T10	Buprofezin 25%SC	1.0 ml	30	7.93 (16.32)	7.93	12.87 (21.02)	12.87
T11	Control		30	0.00 (0.87)	-	0.00 (0.87)	-
SEm ±				0.20		0.18	
CD @ 1%				0.784		0.73	

Note: Values in the parenthesis are angular transformed DAT- Days after Treatment

Table 2: Relative toxicity of selected insecticides against adult whiteflies (3-7 DAT)

Treatment no.	3DAT		4DAT		5DAT		6DAT		7 DAT	
	Per cent mortality	Corrected percent mortality	Per cent mortality	Corrected percent mortality	Per cent mortality	Corrected percent mortality	Per cent mortality	Corrected percent mortality	Per cent mortality	Corrected percent mortality
T1	85.83 (68.03)	84.12	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T2	29.40 (32.83)	20.88	42.87 (40.98)	32.47	53.67 (47.12)	43.17	80.97 (64.14)	74.22	90.90 (72.54)	85.91
T3	84.20 (66.58)	82.29	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T4	52.67 (46.55)	46.96	72.60 (58.69)	67.61	87.77 (69.56)	84.99	96.50 (79.22)	95.26	100.00 (90.00)	100.00
T5	97.13 (80.19)	96.79	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T6	31.67 (34.27)	23.42	37.33 (37.64)	25.93	56.90 (48.97)	47.14	80.07 (63.51)	73.00	95.93 (78.32)	93.70
T7	68.57 (55.92)	64.77	86.47 (68.44)	84.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T8	44.57 (41.89)	37.88	67.37 (55.18)	61.43	93.10 (74.77)	91.54	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T9	32.27 (34.63)	24.09	45.17 (42.24)	35.19	77.77 (61.89)	72.73	90.87 (72.44)	87.63	96.10 (78.61)	93.96
T10	26.77 (31.18)	17.93	35.70 (36.69)	23.99	67.00 (54.94)	59.53	86.93 (68.78)	82.30	93.47 (75.23)	89.89
T11	10.77 (19.19)	-	15.4 (23.11)	-	18.47 (25.47)	-	26.17 (30.79)	-	35.40 (36.51)	-
SEm±	0.29		0.31		0.35		0.30		0.25	
CD @ 1%	1.18		1.22		1.39		1.22		0.99	

Note: Values in the parenthesis are angular transformed DAT- Days after Treatment

Table 3: Relative toxicity of selected insecticides against adult whiteflies (8-11 DAT)

Treatment no.	8 DAT		9 DAT		10 DAT		11 DAT	
	Per cent mortality	Corrected percent mortality	Per cent mortality	Corrected percent mortality	Per cent mortality	Corrected percent mortality	Per cent mortality	Corrected percent mortality
T1	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T2	94.43 (76031)	88.69	97.27 (80.54)	90.59	97.73 (81.28)	78.88	100.00 (90.00)	100.00
T3	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T4	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T5	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T6	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T7	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T8	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00	100.00 (90.00)	100.00
T9	97.77 (81.87)	95.46	98.93 (83.98)	96.33	98.93 (83.98)	90.06	100.00 (90.00)	100.00

T10	97.63 (81.09)	95.19	98.33 (82.51)	94.27	98.33 (82.51)	84.47	100.00 (90.00)	100.00
T11	50.77 (45.46)	-	70.93 (57.35)	-	89.27 (70.91)	-	96.93 (79.86)	-
SEm±	0.25		0.25		0.25		0.17	
CD @ 1%	1.00		0.98		0.98		0.69	

Note: Values in the parenthesis are angular transformed DAT- Days after Treatment

At five days after treatment, Fipronil (100%) recorded cent per cent mortality of adult. The next best treatment was Emamectin benzoate (91.54%) that recorded a higher mortality and was on par with Acephate (84.99%). A lower mortality rate was recorded in Spinosad (72.73%) and Buprofezin (59.53%). The per cent mortality was least in Triazophos (43.17%) and was on par with Azadirhactin (47.14%) (Table 2). At six days after treatment, Emamectin benzoate recorded 100 per cent mortality of adults. The next best treatment that recorded highest mortality was Acephate (95.26%) which was on par with the treatments Spinosad (87.63%) and Buprofezin (82.30%). The lowest mortality rate was recorded in Azadirhactin (73.00%) and was on par with Triazophos (74.22%) (Table 2). At seven days after treatment, there was cent per cent adult mortality in Acephate (100%). The next best treatments that recorded highest mortality were Spinosad (93.96%), Azadirhactin (93.70%) and Buprofezin (89.89%) and were on par with each other, whereas least per cent mortality was recorded in Triazophos (85.91%) (Table 2).

The treatment Azadirhactin (100%) recorded cent per cent mortality of adult whiteflies at eight days after treatment. The next best treatments that recorded highest mortality were Spinosad (95.46%), Buprofezin (95.19%) and Triazophos (28.33 adults) which were on par with each other. The treatment Triazophos (94.43%) recoded the least mortality (Table 3). At ninth day after treatment, Spinosad (96.93%) recorded highest mortality rate and was on par with Buprofezin (94.27%) and Triazophos (97.27%). However Triazophos (97.27%) recorded least adult mortality among all other treatments. At ten days after treatment, the trend in per cent mortality was same as that of observed at nine days after treatment with per cent mortality of 90.06, 84.47 and 78.88 per cent in Spinosad, Buprofezin and Triazophos, respectively. At eleventh days after treatment, all the insecticides recorded cent per cent mortality except untreated control (Table 3).

4. Discussion

Among the eleven treatments, imidachloprid 17.8% SL (T_1), thiamethoxam 25% WG (T_3) and cyantraniliprole 10% OD (T_5) was highly toxic to adult whiteflies which recorded 100 per cent mortality, four days after treatment (DAT). Among these three insecticides, cyantraniliprole recorded significantly higher per cent mortality of adult whiteflies (97.13%) followed by imidacloprid (85.83%) and thiamethoxam (84.20%) at three DAT. [6] Among the test chemicals, cyantraniliprole 10 OD at 60 and 75 g.a.i/ha had knockdown effect and caused 100 per cent whitefly mortality at 48 h. after treatments. Imidacloprid 17.8% SL and thiamethoxam emerged as the nest best treatments in the present study which could be supported by the findings of [2] where the evaluation of imidacloprid against adult whiteflies resulted in mortality from 82% to 96% at 48h after treatments and thiamethoxam at the two lower concentrations resulted 67% and 90% mortality, respectively. Similarly, imidacloprid was reported to be most toxic to *T. vaporariorum* adults compared to other insecticides [19]. On the contrary the results observed that, thiamethoxam was the most toxic insecticide to the aphid with LC50 of 4.1ppm followed by imidacloprid (4.5ppm) [5].

Fipronil 80% WG (T_7), recorded 100 percent mortality five DAT emerging as fourth best treatment under laboratory condition against whitefly adults. Fipronil belongs to a new class of insecticides fiproles and was found to be efficient compared to pyrethroid, organophosphates and carbamate insecticides [12, 13]. Emamectin benzoate 5% SG (T_8) gave 100 per cent mortality of adult whitefly population at sixth DAT recording as fifth best treatment under laboratory condition against whitefly adults. Acephate 75% SP (T_4) caused 100 per cent adult whitefly mortality at seventh DAT emerging as the sixth best insecticide. This was followed by azadirachtin 10000 ppm causing 100 per cent mortality at eight DAT which in accordance with [10] who reported that 100% mortality of *T. vaporariorum* with neemazal was reached 6-9 days post application on tomato.

While at ninth and tenth DAT mortality recorded in spinosad 480% SC (T_9), buprofezin 25% SC (T_{10}) and Triazophos 40% EC (T_2) was 96.33, 94.27, 90.59 and 90.06, 84.47, 78.88 per cent, respectively. However, 100 per cent mortality was recorded in T_9, T_{10} and T_2 only at eleventh DAT. The lower daily mortality from spinosad could be due to its slow penetration rates and slow metabolism once inside the insect body [14-16], which results in such a delayed but steadily increasing activity. Although buprofezin is effective on immature stages and not on adults [7], it showed little fast killing effect on adults [21].

5. Conclusion

From the present study, it can be concluded that, the treatments *viz*., imidachloprid, thiamethoxam and cyantraniliprole were highly toxic to adult whiteflies which recorded 100 per cent mortality four days after treatment and emerged as best insecticides for managing the whiteflies. Among these three insecticides, cyantraniliprole recorded the highest adult mortality comparatively early than imidachloprid and thiamethoxam.

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