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Persistent toxicity of cyantraniliprole, a diamide insecticide against greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) on tomato (*Solanum lycopersicum* L.) grown under protected environment

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Abstract

Persistent toxicity of cyantraniliprole at two different concentrations namely, recommended dose (90 g a.i. ha^{-1}) and double the recommended dose (180 g a.i. ha^{-1}) was determined on tomato (*Solanum lycopersicum* L.) grown under protected conditions against greenhouse whitefly, *Trialeurodes vaporariorum* adults during 2021 and 2022 summer crop. On zero days after the spray (DAS), the residual toxicity of cyantraniliprole was highest which declined significantly with the advancement in duration to 10 and 20 DAS in recommended and double the recommended dose, respectively. Cyantraniliprole (180 g a.i. ha^{-1}) resulted in 50 % mortality of greenhouse whitefly adults upto 7 days after spray, whereas at 90 g a.i. ha^{-1} it lasted upto 3 days. Cyantraniliprole 180 g a.i. ha^{-1} showed highest persistent toxicity (PT) values of 1112.03 and 1064.41 during 2021 and 2022, respectively as compared to cyantraniliprole @ 90 g a.i. ha^{-1}which recorded 484.21 and 473.33 PT value during the respective seasons.

Key words: Cyantraniliprole, greenhouse whitefly, persistent toxicity, protected environment, tomato

Production of vegetable crops under protected cultivation is being hampered greatly by the ravages of insect and mite pests. In India, 60 species of arthropds-pests including insect and mite, belonging to 47 genera from 10 different groups have been identified to be associated with high value crops and out of these 51 insect and mite species are associated with vegetable crops grown under protected conditions. Approximately sixteen species of insect and mite pests are known to attack tomato crop grown under protected cultivation (Kaushik *et al*. 2023). Greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae) is the key pest of tomato in mid-hill regions of Himachal Pradesh (Sood *et al*. 2012; Sood *et al*. 2018). Its higher rate of fecundity and polyphagous habit have rendered it one of the worst pests of crops grown under protected environment and causes economic damage to host plants by sap-feeding and contamination of crop products with honeydew. It causes up to 40% losses in different crops grown under protected condition (Zanic *et al*. 2008).

Cyantraniliprole, belongs to anthranilic diamide group, that targets the ryanodine receptors in insects, activating uncontrolled release of internal calcium stores, consequently, the exposed insects suffer feeding cessation, lethargy, muscle paralysis, and eventually death (Teixeira and Andaloro 2013). Cyantraniliprole showed anti-feedant activity against a number of insects (Gonzale *et al*. 1999; Jacobson *et al*. 2011). The efficacy of an insecticide depends mainly on its initial activity (acute toxicity) against the target pest and its persistence on the particular host (Brevault *et al*. 2009). Both these properties hold significance to determine the adequate doses of insecticides and the time interval of spraying for an effective pest management program (Walgenbach *et al*. 1991). These properties are influenced by various environmental parameters such as temperature, sunlight and rainfall (Mulrooney and Elmore 2000) and also the host on which they are applied against a pest (Xue *et al*. 2010). Several laboratory studies have been done by various workers to test the efficacy of diamide insecticides against lepidopteran pests

(Hardke *et al*. 2011; Saini and Srivastava, 2022; Teja *et al*. 2019). However there are only a few studies on the persistent toxicity of these insecticides against whitefly (*Bemisia tabaci*, *T. vaporariorum*). Therefore, to ascertain the efficacy potential of cyantraniliprole, the present persistent toxicity studies of cyantraniliprole on greenhouse whitefly adults were carried out in summer seasons during 2021 and 2022.

Materials and Methods

Field trial

Persistence of cyantraniliprole residues on tomato grown under protected conditions was studied during summer cropping seasons of 2021 and 2022. Cyantraniliprole was evaluated at its recommended dose (90 g g a.i. ha^{-1}), and double the recommended dose (180 g a.i. ha^{-1}) in the fruiting phase of the crop. Tomato crop was raised in sandy to clay loam soil as per standard package and practices (Anonymous 2018). Tomato crop was sprayed twice at an interval of 15 days. The control plots were sprayed with water only. The fruits and foliage were thoroughly covered with spray fluid to run-off stage. During the spray, care was taken that lower dose was sprayed first, and all necessary precautions were taken to avoid the chances of drifting of spray fluid to another plot. Leaves of tomato crop were brought to the laboratory at 0, 3, 5, 7, 10, 15, 20, 25 and 30 days after spray continued up to when no mortality of adult whitefly was observed on the treated leaves and leaves from the control plots were also brought at same time intervals.

Rearing of test insect

A stock culture of *T. vaporariorum*, was maintained on young potted plants of tomato in laboratory condition. Field collected greenhouse whitefly population was exposed to potted plants inside oviposition cage. The older and heavily infested tomato plants were periodically replaced with fresh potted plants for the availability of stock culture.

The treated tomato leaves were collected after three hours of spray and brought to the laboratory, where the leaves were placed with abaxial surface facing upward over agar gel bed (2%) in petri plates (5 cm diameter). The GHWF adults (n=20) from stock culture were released in each petri plate and sealed with cling film to avoid deposition of moisture on leaves each experiment was replicated thrice. Observations on adult mortality were recorded after 24 hrs of release of adult GHWF.

The observed mortality was corrected by using Abbott's formula (1925) based on mortality in untreated check.

$$\text{Corrected mortality (\%)} = \frac{\text{Mortality in treatment} - \text{Mortality in UTC}}{100 - \text{Mortality in UTC (\%)}}$$

The persistent toxicity values were calculated by the criterion developed by Pradhan (1967) as given below:

Persistent toxicity (PT) = P x T

where, P = Period for which toxicity persisted

T = Average residual toxicity

Also, the number of days up to which 50 per cent mortality was observed was also determined. The average per cent mortality per day was calculated by average percentage mortalities at 0, 3, 5, 7, 10, 15, 20, 25 and 30 days of observations and then dividing the number of observations delineated as under:

$$\text{Average per cent mortality per day (T)} = \frac{\text{Sum of corrected mortalities at different intervals}}{\text{number of observations}}$$

Statistical analysis

The corrected % mortality data obtained at various specific periods was used to calculate mean residual toxicity (T). The persistent toxicity of cyantraniliprole to GHWF was found out by calculating the index called PT value. The PT value is the product of mean % residual toxicity (T) and period (P) for which the toxicity persisted. The mean of persistent toxicity of cyantraniliprole during two seasons (2021 and 2022) were subjected to t-test to compare the means.

Results and Discussion

The data on persistent toxicity of cyantraniliprole at recommended dose (90 g a.i. ha^{-1})and double the recommended doses (180 g a.i. ha^{-1}) respectively on tomato against greenhouse whitefly during summer seasons of 2021 and 2022 are presented in Table 1 to 4. A perusal of data contained in Table 1 revealed that cyantraniliprole resulted in mortality varying from 0.00 to 81.67% and 0.00 to 100% at recommended dose i.e. 90 g a.i. ha^{-1} and double the recommended dose i.e. 180 g a.i. ha^{-1}, respectively on different days of sampling during 2021. On zero day after spray (DAS), the residual toxicity was highest which declined significantly with the advancement in duration to 10 DAS and 20 DAS in the respective

doses of cyantraniliprole. However, no mortality was observed on 15 DAS in treatment comprising recommended dose (90 g a.i. ha^{-1}) and on 25 DAS in double the recommended dose (180 g a.i. ha^{-1}) of cyantraniliprole. Amongst treatments, cyantaniliprole (180 g a.i. ha^{-1}) resulted in maximum mean mortality of GHWF adults.

The data contained in Table 2 revealed cyantraniliprole resulted in mortality of GHWF adults during 2022 varying from 0.00 to 80.00 per cent and 0.00 to 98.33 per cent at recommended and double the recommended dose, respectively on different days of sampling. The maximum residual toxicity was evident on zero DAT which declined significantly with the advancement in duration to 10 DAS in recommended dose and 20 DAS in double dose of cyantraniliprole (180 g a.i. ha^{-1}). Amongst treatments, cyantaniliprole @ 180 g a.i. ha^{-1} resulted in maximum mortality of GHWF adults as compared to cyantraniliprole @ 90 g a.i. ha^{-1}.

A perusal of Table 3 showed the mean mortality of GHWF with cyantraniliprole at it recommended (90 g a.i. ha^{-1}) and double the recommended dose (180 g a.i. ha^{-1}) during summer cropping seasons 2021 and 2022. The mortalities caused by cyantraniliprole showed significance at 1% (t value=0.002 and 0.006 <0.01) during both the years of study. It is evident from Table 4 cyantraniliprole (90 g a.i ha^{-1}) resulted in 50 % mortality of GHWF adults upto 3 DAS, whereas it was 7 DAS in treatment comprising cyantraniliprole @

Table 1. Persistent toxicity of cyantraniliprole to *Trialeurodes vaporariorum* in tomato during summer season 2021

Insecticide	Application rate(g a.i. ha^{-1})	Corrected mortality (%) at 24 HAT on indicated days after spray								
		0 (2h after spray)	3	5	7	10	15	20	25	Mean
Cyantraniliprole	90	81.67	71.67	48.33	27.11	13.33	0.00	-	-	30.26
Cyantraniliprole	180	100.00	93.33	73.33	52.54	41.67	18.33	10.00	0.00	48.65

HAT: hours after treatment

Table 2. Persistent toxicity of cyantraniliprole to *Trialeurodes vaporariorum* in tomato during summer season 2022

Insecticide	Application rate (g a.i. ha^{-1})	Corrected mortality (%) at 24 HAT on indicated days after spray								
		0 (2h after spray)	3	5	7	10	15	20	25	Mean
Cyantraniliprole	90	80.00	68.33	46.67	25.00	16.67	0.00	-	-	29.58
Cyantraniliprole	180	98.33	93.33	71.67	50.88	36.67	16.67	5.00	0.00	46.58

HAT: hours after treatment

Table 3. Comparative persistent toxicity of cyantraniliprole during summer seasons 2021 and 2022

Season	Mean mortality		t-test
	Cyantraniliprole 90 g a.i ha^{-1}	Cyantraniliprole 180 g a.i ha^{-1}	
Summer 2021	30.26	48.65	0.002**
Summer 2022	29.58	46.58	0.006**

** Significance at 1% (0.002 and 0.006 < 0.01)

Table 4. Persistent toxicity index of cyantraniliprole to *Trialeurodes vaporariorum* in tomato during summer seasons 2021 and 2022

Cropping season	Insecticide	Application rate (g a.i. ha^{-1})	X	T	P	PT
Summer 2021	Cyantraniliprole	90	3	48.42	10	484.21
		180	7	55.60	20	1112.03
Summer 2022	Cyantraniliprole	90	3	47.33	10	473.33
		180	7	53.22	20	1064.41

X = number of days upto which at least 50% mortality was observed
T = average per cent mortality per day
P = period in days upto which mortality recorded
PT = persistent toxicity index

180 g a.i. ha^{-1}. The corresponding value of period of toxicity was 10 and 20 days in the respective doses during both the seasons. However the persistent toxicity value for respective doses varied during two seasons. Based on the order of relative persistence toxicity, the value of persistence toxicity index varied from 484.21 to 473.33 in cyantraniliprole @ 90 g a.i. ha^{-1} and 1112.03 to 1064.41 in cyantraniliprole @ 180 g a.i. ha^{-1} during 2021 and 2022, respectively. The descending order of persistence was cyantraniliprole @ 180 g a.i. ha^{-1} > cyantraniliprole 90 g a.i. ha^{-1}.

The present findings on the efficacy of diamide insecticide, cyantraniliprole with novel mode of action against greenhouse whitefly are supported with the results of Han *et al*. (2012) who reported chlorantraniliprole (50 mg L^{-1}) resulted in 100 per cent mortality of diamond backmoth, *Plutella xylostella* larvae at zero day on raddish and mortality declined from 100 to 95.27 per cent at 14 DAT. In another studies by Hardke *et al*. (2011) also reported effectiveness of chlorantraniliprole and cyantraniliprole against armyworm, *Spodoptera frugiperda*. They reported 53.1 per cent mortality of *S. frugiperda* at 3 DAT in grain sorghum. Teja *et al*. (2019) also reported that chlorantraniliprole showed maximum persistent toxicity against 3rd instar larvae of diamond back moth, *Plutella xylostella*. The present results indicating the persistent toxicity of cyantraniliprole residues are in line with the observations of Thakur and Srivastava (2020) who recorded the PT values of chlorantraniliprole @ 0.006% after 72 hrs were recorded as 1542.72 and 1554.24 on cowpea and soybean leaves, respectively.

The present study on the persistent toxicity of cyantraniliprole, a daimide insecticide against greenhouse whitefly revealed cyantaniliprole at double the recommended dose (180 g a.i. ha^{-1}) resulted in maximum mean mortality of GHWF adults as compared to cyantraniliprole at recommended dose (90 g a.i. ha^{-1}) during both years. Cyantarniliprole residues at double the recommended dose persisted longer (7 DAS), as compared to recommended dose of cyantraniliprole (5 DAS) on tomato.

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