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Efficacy of cyantraniliprole a new anthranilic diamide insecticide against *Leucinodes orbonalis* (Lepidoptera: Crambidae) of brinjal

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Abstract

An experiment was carried out both in laboratory and field condition to evaluate the dose mortality response and bioefficacy of a new anthranilic diamide molecule, cyantraniliprole 10 OD against *Leucinodes orbonalis* a serious shoot and fruit borer pest of brinjal. Cyantraniliprole when applied as fruit dip, was 6543 times more toxic to *L. orbonalis* as compared to cypermethrin. The descending order of toxicity of tested insecticides was cyantraniliprole > chlorantraniliprole > flubendiamide > cypermethrin. Under laboratory bioassays the third instar larvae of *L. orbonalis* were found to be more susceptible to cyantraniliprole @ 90 g a.i./ha and recorded highest per cent mortality of 91.66 and 99.00 at 24 and 48 hrs after treatment. In field experiment, cyantraniliprole @ 105 g a.i. ha^{-1} was significantly most effective and recorded lowest per cent fruit damage of 8.92 and 8.25 with highest marketable fruit yield of 18.46 and 22.40 t ha^{-1} during year 2010 and 2011, respectively. The present findings indicate that among different diamide insecticides, cyantraniliprole @ 90-105 g a.i. ha^{-1} proved to be highly effective against *L. orbonalis*. This novel molecule can be used as a new tool by farmers and new component for strengthening integrated pest management (IPM) and insecticide resistance management (IRM) programme for *L. orbonalis*.

Key words

Bioefficacy, Brinjal, Cyantraniliprole, *Leucinodes orbonalis*, Toxicity

Introduction

Solanum melongena commonly know as brinjal (Solanaceae) is the most important and popular vegetable of common man in South and South East Asia. After potato, it ranks second highest consumed vegetable in India, along with tomato and onion. Globally, India is the second largest brinjal producing country after China with 27.1 % share. Here, it is grown in about 0.722 million ha with an annual production of 13.44 million t and productivity of nearly 18.6 t ha^{-1} (NHB, 2013). South Asia accounts for more than 50 % of the world's area under brinjal cultivation (Alam *et al*., 2003). It is an important cash crop for poor and marginal farmers, who transplant it from nurseries at different seasons of the year. Brinjal is proned to attack by many insects pests of which the shoot and fruit borer, *Leucinodes orbonalis* is serious one in South and South East Asian countries (Alam *et al*., 2003; 2006). Damage can often be severe resulting the variable economic yield losses from 37 to 93 % in various states of India (Mall *et al.,* 1992; Choudhary and Gaur, 2009). Infestation starts from nursery continues till harvest and then carried over to the next season. It remains active throughout the year, except for few months during winter. Among different vegetables maximum pesticide usage is in brinjal with 4.60 kg a.i ha^{-1} after chilli (Kodandaram *et al*., 2013). Conventional insecticides *viz.* organophosphates, synthetic pyrethroids and carbmates are generally used to control this insect. Sometimes growers of India and South East Asian country like Bangladesh resort more than 30–40 rounds of sprays during cropping season (Alam *et al*., 2003. Shelton, 2010 and Krishna Kumar *et al*., 2010). Intensive use of pesticides has led to the development of high level of insecticide resistance to a number of conventional insecticides in *L. orbonalis* (Rahman and Rahman, 2009). However, growing concerns about the harmful residues in food, effects on non-target organisms and development of insecticide resistance have necessitated the development of new and safer molecules. Hence, there is great demand and need for new green chemistry molecules with novel mode of action for the management of shoot and fruit borer.

Cyantraniliprole is a second generation new anthranilic diamide molecule with broad spectrum activity against insect pests (Thomas *et al*., 2013). This new molecule selectively binds to the ryanodine receptors (RyRs) in insect muscle cells, resulting in activation of RyRs and causing an uncontrolled release of Ca^{+2} ions from internal stores which leads to depletion of calcium, muscle paralysis and death (Cordova *et al*., 2006 and Sattelle *et al*., 2008). Recently, in India cyantraniliprole is approved and recommended for use in vegetable crops like cabbage, tomato, gherkin, chilli and yet to be registered for use in brinjal. To determine the potential value of any new molecule it is necessary to establish a dose-mortality response, and study its efficacy against target pests to provide baseline data for future resistance monitoring efforts (Cook *et al.,* 2004). Field bio-efficacy data and baseline response of *L. orbonalis* to cyantraniliprole 10 OD is lacking. Therefore, the present study was conducted with an objective to evaluate the toxicity and field efficacy of cyantraniliprole against *L. orbonalis* in brinjal.

Materials and Methods

Test chemicals : The proprietary formulations of insecticides *viz*., cyantraniliprole (Cyazypyr 10 OD), chlorantraniliprole (Coragen 18.5 SC), flubendiamide (Fame 240 SC), cypermethrin (Krycip 25 EC), dimethoate (Tafgor 30 EC) and profenphos (Profex 50 EC) were obtained from their respective source of supply and used in the present investigation.

Laboratory bioassays : The cultures of *L. orbonalis* was established using field collected population from the research farm of Indian Institute of Vegetable Research (IIVR), Varanasi which were not exposed to insecticides. The insects were reared on healthy and untreated brinjal fruits at 26 ºC, 60 % RH, 16:8 h light: dark period and F1 larvae were used for all bioassays.

For dose-mortality studies, six to seven different concentrations of each insecticide were used. In case of bioefficacy studies, three doses of cyantraniliprole *viz*., 60, 75 and 90 g a.i. ha^{-1}, and recommended doses of chlorantraniliprole @ 40 g a.i ha^{-1}, flubendiamide @ 48 g a.i. ha^{-1} and cypermethrin @ 50 g a.i ha^{-1}. were tested. All the insecticide solutions including control were prepared in deionized water containing spreader/sticker at 0.1%.

Fruit dip bioassay method was used to test the toxicity and laboratory efficacy of insecticides to *L. orbonalis*. Healthy and unifested brinjal fruits were thoroughly washed in deionized water, air dried and cut into small discs of 25 mm thickness. Fruit discs were dipped for 30 sec in each insecticide solution and air dried at room temperature on filter paper. Treated fruit discs were transferred to each plastic insect breeding dishes (95 mm x 35 mm) and ten third instar larvae of *L. orbonalis* were released in each dishes. All the plastic dishes containing treated fruits and insects were kept at 26 ± 2 ºC, 60 % RH, 16:8 h light:dark period. All the bioassays were repeated twice, there were three replicates per treatment and mortality was recorded at 24 and 48 hrs after treatment. Morbid insects showing no sign of movement were scored as dead. Mortality in all the treatments was corrected by Abott's formula (Abott, 1925).

Field efficacy : Field trials were conducted on brinjal (cv Purple Round) for two seasons during the year 2010 and 2011 in a randomized block design (RBD), having plot size of 5.75 m^2 with three replicates per treatment, at the farm of Vegetable Research Station, Hyderabad, India. The seedlings were transplanted on 10^{th} August, 2010 and 20^{th} July, 2011. Crop was raised with all the recommended standard agronomic practices, except plant protection. There were seven treatments *viz.*, four different doses of cyantraniliprole 10 OD @ 60, 75, 90 and 105 g a.i. /ha, dimethoate 30 EC @ 300 g a.i. ha^{-1}, profenophos 30 EC @ 500 g a.i./ha as standard checks and an untreated control. All the treatments were applied under warm and sunny conditions with little or no winds using high volume knapsack sprayer fitted with hollow cone nozzle and using 375-500 l of spray fluid per hectare. First spraying was done at 20-25 days after transplanting. Total four sprays were given at an interval of 10-15 days. Observations on per cent fruit borer damage on number basis and yield (kg) per plot after five harvests were recorded. The yield per plot was converted to yield (tonnes) per hectare.

Statistical analysis : The median lethal concentration (LC_{50}) values and fiducial limits were estimated by Probit Analysis (Finney, 1971). The values of relative toxicity of different insecticides were calculated by taking LC_{50} value of cypermethrin as unity (Kodandaram and Swaran Dhingra, 2003). The data on per cent mortality obtained in laboratory efficacy studies and per cent fruit damage in field trials were subjected to one way analysis of variance (ANOVA) after transformation by using SPSS Version 16.0 software.

Results and Discussion

Cyantraniliprole was found to be most toxic to third instar larvae of *L. orbonalis*. The LC_{50} values for cyantraniliprole, chlorantraniliprole, flubendiamide and cypermethrin were 0.62, 1.8, 11.2 and 4057 ppm, respectively. The descending order of toxicity for *L. orbonalis* was cyantraniliprole > chlorantraniliprole > flubendiamide > cypermethrin. On the basis of LC_{50} values, cyantraniliprole, chlorantranilprole, flubendiamide were 6543.54, 2253.88 and 362.23 times more toxic to *L. orbonalis* as compared to cypermethrin (Table 1). The results clearly indicate that the new anthranilic diamide insecticide, cyantraniliprole was highly toxic to the larvae of *L. orbonalis* as compared to other diamide insecticides and cypermethrin.

The third instar larvae of *L. orbonalis* were highly susceptible to all the insecticidal treatments at field doses in comparison to untreated control. Differences in the mortality of *L. orbonalis* to three diamide insecticides *viz.*, cyantraniliprole, chlorantraniliprole, flubendiamide were statistically significant with per cent mortality range between 51.66 to 100 at 48 hrs after treatment. Among different doses of cyantraniliprole @ 90 g a.i. ha^{-1} was found to be most effective with 91.66 and 99.00 % larval mortality of *L. orbonalis* at 24 and 48 hrs after treatment respectively, when tested by fruit dip bioassay method. Chlorantraniliprole was next best treatment with 82.00 and 100 % mortality, whereas conventional insecticide cypermethrin, belonging to synthetic pyrethroid group, exhibited only 52.33 and 66.66 % mortality at 24 and 48 hrs after treatment (Table 2). Mortality of *L. orbonalis* was dose dependent and highest mortality percentage was recorded in cyantraniliprole 90 a.i. ha^{-1} after 24 and 48 hrs after treatment.

High susceptibility of *L. orbonalis* to cyantraniliprole may be attributed to unique mode of action of this new molecule which activates ryanodine receptors (RyRs) and cause an uncontrolled release of Ca^{+2} ions which leads to muscle paralysis and death (Sattelle *et al.,* 2008). Not much literature is available on toxicity of the new insecticide cyantraniliprole against brinjal shoot and fruit borer, *L. orbonalis*. This is the first study to report the effect of cyantraniliprole against *L. orbonalis* in brinjal. However, the present findings corroborates with the studies of Tiwari *et al.* (2013) who reported that the toxicity of cyantraniliprole for *Tamarixia radiata* was 297 fold higher than that obtained for *Diaphorina citri*. Yadav *et.al.,* (2012) also reported that cyantraniliprole at the rate of 0.5, 0.6 and 0.7 ml l^{-1} of water, gave 100 % mortality of *Spodoptera litura* at 72 hrs after exposure in laboratory bioassays. Similarly, Patel *et.al.* (2012) observed higher per cent larval mortality of *S. litura* to cyantraniliprole @ 105 and 90 g a.i. ha^{-1}. Hardke *et al.* (2011) confirmed lower LC_{50} values of chlorantranilprole against *Spodoptera frugiperda.* Sarao and Kaur (2014) also found that chlorantraniliprole @ 40 and 50 g a.i. ha^{-1} was significant in reducing the borer and leaf folder infestation in rice. The present findings were also in conformity with the results of Jacobson *et al.* (2011), Fettig *et al.* (2011) and Foster (2012) who reported the effectiveness of cyantraniliprole against other insect pests of various host plants.

Data on field efficacy of different insecticides against *L. orbonalis* presented in Table 3 clearly indicates that all the treatments reduced fruit damage significantly over untreated control. However, cyantraniliprole @ 105 g a.i. ha^{-1} was found most effective and recorded significantly lowest per cent fruit damage of 8.92 and 8.25 during 2010 and 2011. The next best treatment was cyantraniliprole @ 90 g a.i. ha^{-1} with overall per cent fruit damage of 12.76 and same dose was statistically at par with the standard check profenophos 50 EC in second year season trial. Whereas in dimethoate treated plots the per cent fruit damage was 16.47 and 20.48 during 2010 and 2011, respectively indicating lower efficacy of this conventional insecticides.

Table 1 : Dose-mortality response of *L. orbonalis* to diamide insecticides

Insecticides	*n*	LC_{50} (ppm)	95% Fiducial limits	LC_{90} (ppm)	95% Fiducial limits	Slope ± SE	df	X^2	Relative Toxicity
Cyantraniliprole 10 OD	210	0.62	0.36-1.05	13.56	3.00-37.85	0.954±0.118	5	1.192	6543.54
Chlorantranilprole 18.5 SC	210	1.8	0.90-3.10	28.21	17.47-45.54	1.062±0.131	5	1.051	2253.88
Flubendamide 39.35 SC	210	11.2	8.51–14.71	131.00	121.38-179.08	0.888± 0.175	5	0.971	362.23
Cypermethrin 25 EC	180	4057	3154 - 5218	7961	3501-8104	0.991± 0.055	4	3.196	1.00

In none of the cases, the data were found to be significantly heterogeneous at P= 0.05. ; n= Number of insects tested; Relative Toxicity = LC_{50} of cypermethrin / LC_{50} of other insecticide

Table 2 : Effectiveness of cyantraniliprole 10 OD to *L. orbonalis* by fruit dip bioassay

Treatments	Per cent mortality* ± SE	
	24 HAT*	48 HAT
Cyantraniliprole 10 OD @ 60 g.a.i/ha	51.66(45.96) ± 4.40	66.66(54.74) ± 4.40
Cyantraniliprole 10 OD @ 75 g. a.i/ha	66.67(56.79)±3.33	90.00(71.57) ± 5.77
Cyantraniliprole 10 OD @ 90 g. a.i/ha	91.66(73.22)±4.40	99.00(84.26) ± 0.57
Chlorantraniliprole 18.5 SC @ 40 g. a.i/ha	82.00(64.90)±3.51	100.00(90.00) ± 0.00
Flubendamide 39.35 SC @ 48 g. a.i/ha	70.00(56.79)±2.88	80.00(63.43) ± 11.54
Cypermethrin 25 EC @ 50 g. a.i/ha	52.33(46.34)±5.04	66.66(54.74) ± 4.40
Untretaed Control	0.00(0.00)±0.00	5.00(12.92) ± 2.88
SEm ±	4.98	8.38
CD (P= 0.05)	3.44	5.79

* Hours after treatment; *Figures in parentheses are angular transformed values

Table 3 : Field bioefficacy of cyantraniliprole 10 OD against *L. orbonalis* of brinjal

Treatments	Dose (g.a.i. ha^{-1})	Per cent fruit damage* Season I (2010)	Per cent fruit damage* Season II (2011)	Overall mean
Cyantraniliprole 10 OD	60	18.20(25.24)	18.89(25.72)	18.54
Cyantraniliprole 10 OD	75	15.79(23.40)	16.79(24.19)	16.28
Cyantraniliprole 10 OD	90	12.38(20.59)	13.15(21.23)	12.76
Cyantraniliprole 10 OD	105	8.92(17.38)	8.25(16.63)	8.56
Dimethoate 30 EC	300	16.47(23.96)	20.48(24.95)	18.47
Profenophos 50 EC	500	19.75(26.40)	13.47(21.72)	16.61
Untreated Control		35.28(36.45)	24.18(28.79)	29.73
SEm ±		0.582	0.750	
CD (P= 0.05)		1.765	2.310	
CV		4.2	5.6	

*Figures in parentheses are angular transformed values

Table 4 : Effect of cyantraniliprole 10 OD on marketable fruit yield of brinjal

Treatments	Dose (g.a.i. ha^{-1})	Marketable fruit yield (t ha^{-1}) Season I (2010)	Marketable fruit yield (t ha^{-1}) Season II (2011)	Overall average yield (t ha^{-1})
Cyantraniliprole 10 OD	60	9.93	9.60	9.76
Cyantraniliprole 10 OD	75	11.38	14.33	12.85
Cyantraniliprole 10 OD	90	14.77	19.82	17.30
Cyantraniliprole 10 OD	105	18.46	22.40	20.43
Dimethoate 30 EC	300	15.39	15.30	15.34
Profenophos 50 EC	500	16.23	16.01	16.12
Untreated Control		6.57	7.33	6.95
SEm ±		0.429	0.662	
CD (P= 0.05)		1.30	2.040	
CV		5.8	7.7	

The present observations on field efficacy of cyantraniliprole are in conformity with Mandal (2012) who reported that cyantraniliprole @ 105 and 90 g a.i. ha^{-1} was highly effective against the fruit borer, *Helicoverpa armigera* in tomato. Yadav *et.al*. (2012) also reported that cyantraniliprole @ 80 g a.i./ha resulted in highest leaf damage reduction by flea beetle, *Scelodonta strigicollis* in grapes. Tiwari *et al.* (2013) acknowledged that foliar application of cyantraniliprole reduced numbers of *Diaphorina citri* adults and nymphs in citrus. Mishra and Mukherjee (2012) revealed that cyantraniliprole @ 105 and 90 g a.i. ha^{-1} to be most effective against red pumpkin beetles *Aulacophora foveicollis* on gherkins. Hardke *et al*. (2011) reported high residual efficacy of cyantraniliprole to larvae of *Spodoptera frugiperda* with more than 40 per cent mortality at 28 days after treatment (DAT). Anil and Sharma (2010) found, emamectin benzoate (0.002%) was superior in reducing that fruit infestation by *L. orbonalis* in brinjal. Findings of the present study on efficacy of diamide insecticide for the management of *L. orbonalis* in brinjal were similar to that of Mishra (2008), Jagginavar *et al.* (2009) and Abdul Latif *et al*. (2009).

The marketable fruit yield (t ha^{-1}) was significantly more in all the treatments as compared to untreated control (Table 4). Highest fruit yield was recorded in plots treated with cyantraniliprole @ 105 g a.i. ha^{-1} during year 2010 (18.46 t ha^{-1}) and year 2011 (22.40 t ha^{-1}). This treatment was followed by cyantraniliprole @ 90 g a.i. ha^{-1} with a mean yield of 14.77 and 19.82 t ha^{-1} during the year 2010 and 2011. The overall average yield data also revealed similar results indicating superiority of cyantraniliprole @ 105 and 90 g a.i. ha^{-1} over other treatments with highest fruit yield of 20.43 and 17.30 t ha^{-1}, respectively. Greater fruit yield in cyantraniliprole treated plots may be attributed to the suppression of *L. orbonalis* population by cyantraniliprole due to its unique mode of action and longer residual efficacy. Thus, the present studies suggests that among different diamide insecticides, *viz.,* cyantraniliprole, chlorantraniliprole, flubendiamide and cyantraniliprole @ 90-105 g a.i. ha^{-1} was highly effective against brinjal shoot and fruit borer, *L. orbonalis* under both laboratory and field conditions. The baseline toxicity data reported here will serve as ready reckoner in future, for monitoring shifts in susceptibility among populations of *L. orbonalis* in India and elsewhere for the purpose of resistance monitoring. This novel molecule can be used as a new tool by farmers for the management of shoot and fruit borer in brinjal. It can also be exploited as a new component for strengthening integrated pest management (IPM) and insecticide resistance management (IRM) programme for *L. orbonalis*.

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