Indian Journal of Agricultural Sciences **89** (11): 1881–4, November 2019/Article
https://doi.org/10.56093/ijas.v89i11.95334

Cyantraniliprole mode of action against *Diaphorina citri* and *Papilio demolius* in *Citrus reticulata*

ANJITHA GEORGE[1] ,C N RAO[2], V N DHENGRE[3] and SUCHITRA ROY[4]

ICAR-Central Citrus Research Institute, Nagpur, Maharashtra 440 033, India

Received: 30 January 2019; Accepted: 22 April 2019

ABSTRACT

Anthranilic diamide insecticides are currently in use for pest management in many crops across the world. There was an urging pressure for a newer chemistry for the management of sucking and defoliator pests of citrus in India. Hence, field studies were conducted at ICAR-Central Citrus Research Institute, Nagpur to evaluate cyantraniliprole HGW86 10% w/v OD during 2016–17 as this molecule is not yet registered for use in citrus. The effects of cyantraniliprole HGW86 10% w/v OD (50, 60, and 70 g a.i./ha) along with two standards (Imidacloprid 17.8 SL @ 10g a.i./ha, thiamethoxam 25%WG @ 25g a.i./ha) against *Diaphorina citri* Kuwayama and *Papilio demolius* L. were investigated in the citrus orchards (> five years old) for two seasons. Application of cyantraniliprole @ 60g a.i./ ha and 70g a.i./ha were found to be significantly effective in management of citrus psylla (10.38 psylla/5cm twig) and lemon butterfly (2.68 larvae/plant), respectively. In addition, cyantraniliprole was found to be less toxic to predators in comparison to standards and thus may have less impact on biological control programmes. There was no phytotoxicity symptoms observed in treated plots. Percent increase in yield of 40.46 over control plots was recorded from plots treated with cyantraniliprole HGW86 10% w/v OD@ 70 g a.i./ha during the study. Generation of bio-efficacy data against different citrus insect pests will help to develop and integrate novel tools for the successful management of the pests and also to prevent the development of insecticide resistance. Based on the results of our present study, this new molecule can be recommended as an alternative for the increased usage of neonicotinoids against sucking insect pests of citrus to slow down development of resistance.

Key words: Bio-efficacy, Citrus psylla, Cyantraniliprole, Lemon butterfly, Yield

In India, about 250 insect pests have been reported infesting different citrus cultivars. Citrus butterfly, leaf miner, citrus psylla, blackfly, whitefly, scales, bark eating caterpillar etc are the major pests that cause severe damage to the citrus crop (Nayar *et al.* 1976). Asian citrus psylla (ACP), *Diaphorina citri* Kuwayama is a homopteran insect pest which feeds on the phloem of *Citrus* spp. and other related rutaceous plants. Besides causing direct damage, it is an efficient vector of the bacterium, *Candidatus liberibacter asiaticus* which causes deadly greening disease. Lemon butterfly, *Papilio demoleus* L. is another economically important pest whose larval forms cause serious damage by devouring large quantity of foliage of cultivated species of citrus during the later stages of their development (Singh 1993). The caterpillars feed on the young foliage at the nursery stage and also on young flushes of grown up trees leaving behind only the midrib of the lamina. In case of severe infestation, entire tree is defoliated.

Several bio-rationales and insecticides have been evaluated for the management of sucking and chewing pests in citrus. Current reliance on aggressive application of insecticides has not only proven to be economically challenging but chances of development of resistance in insect populations is of major concern. Second-generation anthranilic diamide insecticides are now currently registered and used worldwide against insect pests of tuber/corms, root vegetables, bulbs, leafy vegetables, legumes, *Brassica* sp., cucurbits, pome and stone fruits, tree nuts, tobacco etc (Anonymous 2017). Unique mode of action involving activation of ryanodine receptors (RyRs), which play a critical role in muscle function is observed in this group (Lahom *et al.* 2005, Cordova *et al.* 2005). The first-generation anthranilic diamide insecticide chlorantraniliprole has shown promising results in the management of lepidopteran, hemipteran and coleopteran pests (Hardke *et al.* 2011, Li *et al.* 2012). Cyantraniprole has also been registered extremely effective against sucking and lepidopterous pests, including those resistant to neonicotinoid and pyrethroid insecticides (Li *et al.* 2012). Registration of cyantraniprole is still pending for use in citrus in India and hence, the present study was carried out to generate bio-efficacy data for cyantraniprole against *D. citri* and *P. demoleus* under central Indian conditions through field studies. In addition,

Present address: [1]Scientist (anjithakitty@gmail.com), [2]Principal Scientist (nandikesh70@gmail.com), [3]Senior Technical Officer (vijaydhengre@gmail.com), [4]Field Assistant (suchitraroy86@gmail.com).

cyantraniliprole was evaluated against bioagents for safety and also observed for any phytotoxicity effects under available circumstances.

MATERIALS AND METHODS

Experimental unit: The field experiments were conducted to evaluate the efficacy of preregistered formulated material (HGW86 10% w/v OD) provided by EI DuPont India Pvt Ltd, Gurgaon during Ambia flowering (Feb-March, 2016, 2017) against citrus psylla in a 10 year old *Citrus reticulata* Blanco orchard (Nagpur mandarin); Hasta flowering (Oct-Dec, 2016) and summer season (April-May, 2017) for lemon butterfly in a 5 years old pre-bearing Nagpur mandarin orchard planted at a spacing of 6m × 6m in the experimental farm ($21^0 11'5.86"$ & $77^0 25'16.2"$) of ICAR-Central Citrus Research Institute (CCRI), Nagpur. The experiments were arranged in a randomized block design (RBD) with four replicates and two trees per replication. Three doses of cyantraniliprole HGW86 10% w/v OD (50, 60, and 70 g a.i./ha) were evaluated with control (untreated) and two standard checks, imidacloprid 17.8% SL @ 10g a.i./ha (Confidor, Bayer Crop Science, Mumbai) and thiamethoxam 25% WG @ 25 g a.i./ha (Actara, Syngenta India Limited, Pune). Spray volume of 1000 l water per ha was used and sprayings were done using knapsack sprayer fitted with hollow cone nozzle and sprayed till the spray solution caused visible leaf runoff.

Statistical analysis: Observations on psylla population/5cm twig and lemon butterfly larvae/plant were taken before and 14 days after the treatment. The yield data was also recorded per tree and converted to tonnes/ha. Observations on *Mallada desjardinsi* Navas and *Cheilomenus* (=Menochilus) *sexmaculatus* (Fabricius) count/tree/two minutes (visual observation) were recorded before and 14 days after spraying. The visual observations on psylla population, lemon butterfly larval count and bioagents were subjected to square root (x+0.5) transformation to stabilize variance and analysed by ANOVA. Significant means were separated using Tukey's honest significant difference (HSD).

Phytotoxicity: Phytotoxicity effects were studied for two doses, viz. Cyantraniliprole HGW86 10% w/v OD at 60 and 120 g a.i./ha along with untreated control on 10 year old Nagpur mandarin orchard at ICAR-CCRI farm, Nagpur. The extent of phytotoxicity was recorded based on following score: 0(No phytotoxicity), 1(1-10), 2(11-20), 3(21-30), 4(31-40), 5(41-60), 6(51-60), 7(61-70), 8(71-80), 9(81-89), 10(91-100). All the plants were critically observed for any phytotoxicity symptoms like generalized yellowing, chlorosis, necrotic spots on leaf surface, curling of leaves, wilting, deformed leaves, scorching, epinasty/hyponasty etc. Prevailing average maximum and minimum temperature humidity was recorded from Regional Meteorological Centre, Indian Meteorological, Nagpur during the experimental period.

RESULTS AND DISCUSSION

Effect of insecticide treatments on citrus psylla: Results of field evaluation indicated that citrus psylla population ranged from 23.35 to 32.05 and 28.43 to 32.81 population/5cm twig, with treatment difference being non significant during *Ambia* 2016 and 2017, respectively

Table 1 Efficacy of cyantraniliprole HGW86 10% w/v OD against citrus psylla, *D.citri* and lemon butterfly, *P. demoleus* in Nagpur mandarin orchard (season I & II)

Treatment	Citrus psylla (population/5cm twig)					Lemon butterfly (number of larvae/plant)					Yield (tonne/ha)	Per cent increase of yield over UTC
	Ambia 2016		Ambia 2017		Pooled over spray and periods	Hasta 2016		Summer 2017		Pooled over spray and periods		
	BS	14 DAS	BS	14 DAS		BS	14 DAS	BS	14 DAS			
T_1=Cyantraniliprole @ 50 g a.i./ha	28.77 (32.42)	13.26 (3.58)^b	30.32 (5.50)	14.18 (3.76)^b	13.72 (3.70)^b	10.75 (3.27)	3.94 (1.98)^b	12.00 (3.46)	4.45 (2.10)^b	4.75 (2.10)^b	16.1^b	23.00
T_2=Cyantraniliprole @ 60 g a.i./ha	23.35 (27.44)	10.04 (3.11)^a	29.62 (5.43)	12.41 (3.37)^a	11.16 (3.33)^a	9.12 (3.01)	3.61 (1.89)^b	10.50 (3.23)	4.19 (2.04)^b	4.19 (2.04)^b	18.3^a	39.60
T_3=Cyantraniliprole @ 70 g a.i./ha	29.13 (32.60)	9.83 (3.07)^a	32.81 (5.72)	10.89 (3.20)^a	10.38 (3.22)^a	10.12 (3.17)	2.24 (1.49)^a	11.25 (3.34)	2.68 (1.63)^a	2.68 (1.63)^a	18.4^a	40.46
T_4=Imidacloprid @ 10 g a.i./ha	27.89 (31.84)	15.94 (3.95)^c	28.43 (5.31)	16.09 (3.93)^b	16.04 (4.00)^c	9.17 (3.02)	6.03 (2.45)^c	10.00 (3.16)	6.50 (2.54)^c	6.26 (2.50)^c	15.7^b	19.84
T_5=Thiamethoxam @ 25 g a.i./ha	31.05 (33.85)	16.56 (4.03)^c	29.50 (5.42)	16.40 (3.97)^b	16.53 (4.06)^c	11.62 (3.40)	7.17 (2.67)^d	12.50 (3.53)	7.56 (2.74)^d	7.36 (2.71)^d	15.8^b	20.60
T_6=Control	32.05 (34.46)	22.60 (4.71)^d	31.83 (5.62)	23.04 (4.77)^c	22.85 (4.77)^d	12.50 (3.52)	9.42 (3.06)^e	13.25 (3.62)	9.62 (3.10)^e	9.52 (3.08)^e	13.1^c	-
CD (p=0.05)	NS	0.16	NS	0.26	0.15	NS	0.16	NS	0.20	0.16	1.41	-
CV (%)	-	2.98	-	4.61	2.65	-	4.91	-	5.53	4.64	5.78	-

BS, Before spray; DAS, Days after spray; NS, Non significant; 14 DAS, Mean of 14 days after spraying. Values were transformed to square root (X+0.5) when analyzing ANOVA. Figures in the same column with same letter (s) do not differ significantly (P>0.05)

before initiation of spray. All the treatments were significantly superior over control irrespective of experimental period (Table 1). During the first season (Ambia 2016), psylla population was significantly low in T_3 (9.83 population/5cm twig) but was at par with T_2 (10.04 population/5cm twig) at 14 DAS. Since psylla infestation was below ETL levels at 14 DAS, second spray was not given (Table 1). Similar results were observed during Ambia, 2017 with pooled mean (14 days after spray) data showing significantly less psylla population/5cm twig in T_3 (10.89 population/5cm twig) and T_2 (12.41 population/5cm twig) than other treatments. Overall mean values also indicated that all the insecticidal treatments were significantly superior to control and significantly lowest citrus psylla population of 10.38 psylla population/5cm twig was recorded with application of cyantraniliprole HGW86 10% w/v OD @ 70g a.i./ha over a period of 30 days; but was at par with cyantraniliprole @ 60g a.i./ha (11.16 psylla population /5cm twig). Both the doses of cyantraniliprole @ 70 and 60g a.i./ha were found equally effective against citrus psylla (Table 1).

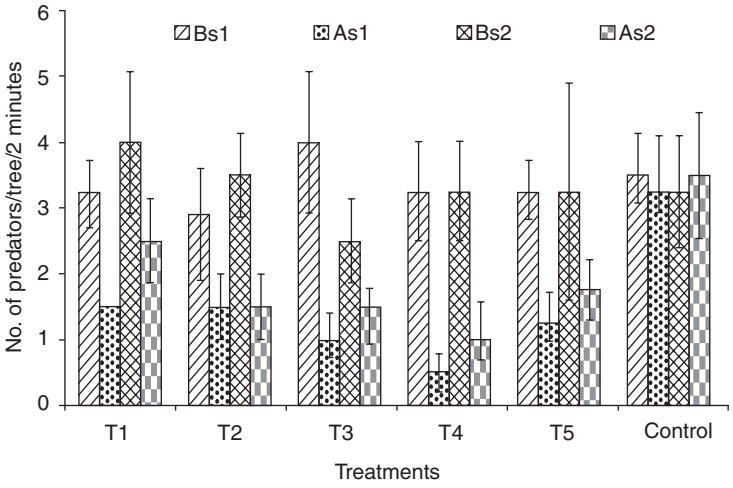

Fig 1 Abundance of predators before and after spraying with insecticides.

Effect of insecticide treatments on lemon butterfly: Lemon butterfly larval population ranged from 9.12 to 12.50 and 10.00 to 13.25 larvae/plant with treatment difference being non-significant during Hasta 2016 and Summer 2017, respectively before initiation of spray. All the treatments were significantly superior over control irrespective of experimental period (Table 1). During Hasta, 2016, at 14 DAS, larval population of lemon butterfly significantly reduced in T_3 with lowest population count of 2.24 larvae/plant followed by T_2 (3.61) and T_1 (3.94 larvae/plant). In the second season also, similar trend was observed. Among the other treatments T_2 with 60g a.i./ha and T_1 with 50g a.i./ha recorded low lemon butterfly larval population than T_4 imidacloprid 17.8% SL @ 10g a.i./ha and T_5 thiamethoxam 25%WG@ 25 g a.i./ha. Results of data pooled over spray period and seasons revealed that all the insecticidal treatments were significantly superior to control and significantly lowest lemon butterfly infestation of 2.68 larvae/plant in cyantraniliprole HGW86 10% w/v @ 70g a.i./ha was recorded over a period of 30 days.

Phytotoxicity: The average maximum, minimum temperature, humidity of 25.80^{0}C of 12.80^{0}C, 36.33% was recorded during the experimental period from February to March 2016 and from 33.39^{0}C, 16.29^{0}C, 55.71% was recorded during from February to March 2017. Results of phytotoxicity studies showed that the two doses of cyantraniliprole HGW86 10% w/v OD @ 60 and 120g a.i./ha did not exhibit any phytotoxicity symptoms on treated plants.

Safety to predators: Safety of predominant predators in citrus ecosystem, viz. *M. desjardinsi* and *C. sexmaculatus* was observed in the treated and control plots based on visual observations tree/two minutes. Control plots recorded relative abundance of predators while plots treated with imidacloprid and thiamethoxam led to significant reduction in number of predators after sprays (Fig 1).

Fruit yield: Interaction of insecticides within observation days and seasons had significant impact of insecticidal treatments on fruit yield of Nagpur mandarin. Cyantraniliprole @ 70g a.i./ha recorded highest yield of 18.4 tonne/ha but was at par with @ 60g a.i./ha (18.3 t/ha) (Table 1).

This is the first report to combine field evaluation of this new mode of action against sucking and chewing pests of citrus in India. Cyantraniliprole is effective against a range of insect pests of various host plants (Hardke *et al.* 2011, Fettig *et al.* 2011, Foster *et al.* 2012). From our studies, it can be concluded that cyantraniliprole HGW86 10% w/v OD @ 60g a.i./ha is effective against citrus psylla and @70 g a.i./ha against lemon butterfly. There are few literatures regarding bio-efficacy of cyantraniliprole (HGW86) against nymphs and adults of *D. citri* and lemon butterfly in citrus across the world implying the present finding a first report from India. Foliar and drench applications of cyantraniliprole at the rates of 1.1, 1.5 and 2.2 l/ha were found highly effective in reducing populations of *D. citri* along with the secondary pest, *Phyllocnistis citrella* Stainton (Tiwari *et al.* 2013). Cyantraniliprole has been reported to be effective against both adults and nymphs of the silver leaf whitefly, in addition to killing leaf miner and caterpillar pests (Smith 2013). Two higher doses of cyantraniliprole 10% OD, i.e. 90 and 105 g a.i./ha was found highly effective in managing the population of aphid, thrips and whitefly in cotton (Patel *et al.* 2014). In similar line, our results also confirm that higher two doses of cyantraniliprole (HGW86) @ 60 and 70 g a.i / ha is effective for sucking as well as defoliator pests in citrus. Treatment of cyantraniliprole 10% OD @ 60 g a.i./ha was also found effective as it provided excellent protection against aphid, thrips and *Helicoverpa armigera* (Hübner) in potato (Lodaya *et al.* 2017).

Cyantraniliprole has been registered for use against lepidopteran pests. From our study, the highest dose of cyantraniliprole 10% OD gave significantly best results. Cyantraniliprole 10% OD @ 90 g a.i./ha registered

significantly the least number of *H. armigera* larvae (0.58 larvae/ plant) than the rest of treatments except cyantraniliprole 10% OD @ 75 and 60 g a.i./ha (0.69 and 0.73 larvae/plant) with which it remained at par (Lodaya *et al.* 2017). The superiority of chlorantraniliprole 18.5 SC @ 0.15 ml/l in the management of anar butterfly may be due to the novel mode of action of anthranilic daiamide, i.e. chlorantraniliprole (Nadaf 2017). Cyantraniliprole @ 80 g a.i./ha which was the highest dose resulted in highest leaf damage reduction by flea beetle and was at par with cyantraniliprole at the rate of 70 g a.i./ha and thiamethoxam (62.5 g a.i./ha) and spinosad (112.5 g a.i./ha) (Yadav *et al.* 2012). Exposure of the pest species typically results in rapid feeding cessation within a few hours of exposure, however the time to death may take 3 to 6 days, depending upon the species. There were no symptoms of phytotoxicty in the treated plots even at double the most effective dose. The greater fruit yield recorded in cyantraniliprole treated plots in the present study may be attributed to the anti-feedant effect of cyantraniliprole decreasing leaf and fruit damage. In agreement, cyantraniliprole showed anti-feedant activity (Gonzales - Coloma *et al.* 1999, Jacobson *et al.* 2011) against a number of insects. Bioagent population (coccinellids and chrysopids) was significantly superior in three doses of that cyantraniliprole (50, 60 and 70 g a.i./ha) after control plots. Neonicotinoid sprayed plots recorded lowest bioagent population.

Anthranillic diamide group of insecticide chlorantraniliprole have been reported safe to coccinellid predators which corroborates with the present findings (Misra 2011). Spraying cyantraniliprole during times of the year when bioagents are active may spare these biological control agents in comparison with other broad-spectrum chemistries and hence can easily be incorporated in an Integrated Pest Management programme. Further, cyantraniliprole has completely different mode of action, by acting on ryanodine receptors, thus, it also has ability to support insecticide resistance management programme.

ACKNOWLEDGEMENT

This study is a part of the Contract research project funded by E I DuPont India Private Limited, Gurgaon, Haryana, India.

REFERENCES

Anonymous. 2017. Dupont™ EXIREL™ insecticide, DFU Booklet, 36p.

Cordova D, Benner E A, Sacher M D, Rauh J J, Sopa J S, Lahm G P, Selby T P, Stevenson T M, Flexner L, Gutteridge S, Rhoades D F, Wu L, Smith R M and Tao Y. 2005. Anthranilic diamides: A new class of insecticides with a novel mode of action, ryanodine receptor activation. *Journal of Pesticide Biochemistry and Physiology* **84**: 196-214.

Fettig C J, Hayes C J, McKelvey S R and Mori S R. 2011. Laboratory assays of select candidate insecticides for control of *Dendroctonus ponderosae*. *Pest Management Science* **67**: 548–55.

Foster S P, Denholm I, Rison J, Portillo H E, Margaritopoulis J and Slater R. 2012. Susceptibility of standard clones and European field populations of the green peach aphid, *Myzus persicae*, and the cotton aphid, *Aphis gossypii* (Hemiptera:Aphididae), to the novel anthranilic diamide insecticide cyantraniliprole. *Pest Management Science* **68**: 629–33.

Gonzales-Coloma A, Gutierrez C, Hubner H, Achenbach H, Terrero D and Fraga B M. 1999. Selective insect antifeedant and toxic action of ryanoid diterpenes. *Journal of Agricultural and Food Chemistry* **47**: 4419–24.

Hardke J T, Temple J H, Leonard B R and Jackson R E. 2011, Laboratory toxicity and field efficacy of selected insecticides against fall armyworm (Lepidoptera: Noctuidae). *Florida Entomologist* **94**: 272–8.

Jacobson A L and Kennedy G G. 2011. The effect of three rates of cyantraniliprole on the transmission of tomato spotted wilt virus by *Frankliniella occidentalis* and *Frankliniella fusca* (Thysanoptera: Thripidae) to *Capsicum annuum*. *Crop Protection* **30**: 512-15.

Lahom G P, Selby T P, Freudenberger J H, Stevenson T M, Myers B J and Seburyamo G. 2005. Insecticidal anthranilic diamides: a new class of potent ryanodine receptor activators. *Bioorganic and Medicinal Chemistry Letters* **15**: 4898–4906.

Li X, Degain B A, Harpold V S, Marcon P G, Nichols R L and Fournier A J. 2012. Baseline susceptibilities of B- and Q-biotype *Bemisia tabaci* to anthranilic diamides in Arizona. *Pest Management Science* **68**: 83–91.

Lodaya J P, Patel N B, Patel R D and Acharya. 2017. Bioefficacy of cyantraniliprole 10% OD W/V (HGW86 10 OD) against pests of potato. *International Journal of Current Microbiology and Applied Sciences* **6**(7): 309–17.

Misra H P. 2011. Bio-efficacy of chlorantraniliprole against shoot and fruit borer of brinjal, *Leucinodes orbonalis* Guenee. *Journal of Insect Science* **24**(1): 60–4.

Nadaf A M. 2017. Bioefficacy of newer insecticides against anar butterfly, *Deudorix isocrates* Fab., on pomegranate. *Journal of Entomology and Zoology Studies* **5**(3): 1655–57.

Nayar K K, Ananthakrishnan B V and David B V. 1976. *General and Applied Entomology,* p 486. Tata McGraw Hill Publishing Co. Ltd. New Delhi.

Patel R D, Bharpoda T M, Patel N B and Borad P K. 2014. Bio-efficacy of cyantraniliprole 10% OD – An anthranilic diamide insecticide against sucking pests of cotton. *Bioscan* **9**(1): 89-92.

Singh S P. 1993. Species composition and diapause in citrus butterflies. *Journal of Insect Science* **6**: 48–52.

Smith H A. 2013. 'Managing diamide Resistance in Florida Tomato'. *http://edis.ifas.ufl.edu*

Tiwari S and Stelinski L L. 2013. Effects of cyantraniliprole, a novel anthranilic diamide insecticide, against Asian citrus psyllid under laboratory and field conditions. *Pest Management Science* **69**: 1066–72.

Yadav D S, Kamte A S and Jadhav R S. 2012. Bio-efficacy of cyantraniliprole, a new molecule against *Scelodonta strigicollis* Motschulsky and *Spodoptera litura* Fabricius in grapes. *Pest Management in Horticultural Ecosystems* **18**(2): 128-34.