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Assessment of cross-resistance in South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

N. R. PRASANNAKUMAR*, N. JYOTHI, G. RAMKUMAR, R. ASOKAN# and V. SRIDHAR

Division of Crop Protection, #Division of Basic Sciences

ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake, Bengaluru-560089, India

***E-mail:** prasannakumar.nr@icar.gov.in

ABSTRACT: Laboratory experiments were carried out to assess the development of cross resistance in selected resistant populations of South American tomato moth, *Tuta absoluta*. Insecticidal bioassays were carried for the different field population (G1) *viz.,* Bangalore, Madurai, Salem and Kolar to assess the resistance status. The resistance population from the bioassay were further subjected to different insecticides (flubendiamide39.35SC, indoxacarb14.5SC, cyantraniliprole10.25SC, emamectin benzoate 5SG, spinosad 45SC and spinetoram11.1SC) to determine development of cross resistance if any. From the study, flubendiamide resistance Bangalore population showed positive cross resistance to cyantraniliprole and spinosad. Cyantraniliprole resistance population from Madurai and Salem showed cross resistance to indoxacarb, flubendiamide and emamectin benzoate, and Kolar indoxacarb population to flubendiamide, cyantraniliprole and emamectin benzoate. The result from the present study thus suggests proper rotation of the insecticides with different modes of action to prevent resistance development in *T. absoluta*.

Keywords: Bioassay, insecticides, resistance, cross resistance**,** IRM

INTRODUCTION

The tomato leaf miner, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) is a micro lepidopteron of South America (Torres *et al*., 2001), infesting tomato (Guenaoui, 2008). *T. absoluta* larvae can completely destroy the tomato crop by extensive mining of leaves, stems and buds, and burrowing in the fruits thus the fruits become unmarketable which lead to yield losses up to 100 per cent (Viggiani *et al*., 2009). The important method of management of *T. absoluta* is application of insecticides, however excessive and indiscriminate usage of insecticides cause a variety of hazards such as adverse effect on non target organisms, development of multi fold insecticidal resistance in insect pests and resurgence of secondary insect pests. Since *T. absoluta* has short life cycle, development of resistance against different group of insecticides is rapid (Prasannakumar *et al*., 2020). Failure of *T. absoluta* control even with high level of insecticide applications has been recorded in many parts of the world. For instance, development of resistance to most of the insecticides like abamectin, cartap, deltametrin, methamidophos, spinosad and permethrin was reported from Brazil, Chile and Argentine (Moore, 1983; Siqueira *et al*., 2000; Lietti *et al*., 2005; Reyes *et al*., 2012). In India, reduced susceptible of different *T. absoluta* populations (Bangalore, Kolar, Madurai, Salem and Anantapur) to different classes of insecticides like flubendiamide, indoxacarb and cyantraniliprole has also been reported (Prasannakumar *et al*., 2020). In the present study, extent of cross -resistance in these different population is determined and discussed.

MATERIALS AND METHODS

Insect culture and bioassay

Tuta absoluta resistant populations from our previous studies (Prsannakumar *et al*, 2021) were maintained at Vegetable Entomology Laboratory, Division of Crop Protection, ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru. The resistant populations were further exposed to different insecticides such as Oxadiazines group: indoxacarb14.5SC, Diamides group: flubendiamide 39.35SC and cyantraniliprole 10.25SC, Avermectins group: emamectin benzoate 5SG and Spinosyns group: spinosad 45SC, spinetoram 11.1SC to determine the possible cross resistance levels.

Leaf dip bioassay of insecticides on *T. absoluta* was carried out as per the Insecticide Resistance Action Committee (IRAC 2013) and Prasannakumar *et al.* (2021). Mortality was calculated after 24h, 48h, 72h and 96h of insecticide exposure using a soft brush. The cross resistance was calculated by dividing LC_{50} value of G4th generation (lab and insecticide exposed) with the LC_{50} value of G1 population (field population) of each insecticide and thus the relative degree of cross resistance was assessed by using the formula as suggested by Ramasubramanian and Regupathy (2004).

Cross resistance (CR) = LC_{50} of F4 (selected) / LC_{50} of F1 (field population)

CR = >1 (Positive), CR = <1 (Negative)

RESULTS AND DISCUSSION

The flubendiamide (1.4-RR) resistant population from Bangalore, cyantraniliprole resistant population from Madurai (1.231-RR) and Salem (1.45-RR), and indoxacarb resistant population (2.07-RR) from Kolar were selected from our previous experiments, and used in the present study (Prasannakumar *et al*., 2021). Bangalore flubendiamide resistance population at G4 generations showed positive cross resistance to cyantraniliprole (1.37-fold) and spinosad (1.02 fold) (Table 1). Similarly, Madurai cyantraniliprole resistant population showed cross resistance at G4 generation for the insecticides- indoxacarb (1.0), flubendiamide (1.16) and emamectin benzoate (1.01) (Table2). Likewise, the Salem cyantraniliprole resistant population showed cross resistance at G4 generations to indoxacarb (1.44), flubendiamide (1.15) and spinosad (1.06) (Table 3). Whereas, Kolar indoxacarb resistant population showed positive cross resistance to cyantraniliprole (1.6), flubendiamide (1.8) and emamectin benzoate (1.0) at G4 generation (Table 4).

Cross resistance is the mechanism when the species confers resistance to two or more compounds which involves same gene conferring resistance to different chemicals. Cross-resistance is usually present among pesticides sharing similar binding target sites

Table 1. Assessment of cross resistance in *T. absoluta* Bangalore population to Flubendiamide

Insecticide	n[a]	LC_{50} LCL-UCL (95% confidence limit)	LC_{90} LCL-UCL (95% confidence limit)	χ^2	df	RR
Indoxacarb	100	10.621 (8.329-12.680)	20.36 (17.865-23.564)	3.10	4	0.96
Cyantraniliprole	100	12.410 (5.260-10.554)	19.310 (14.563-24.650)	1.21	4	1.370
Emamectin benzoate	100	7.0563 (4.230-10.236)	12.369 (8.563-17.568)	3.64	4	1.0
Spinosad	100	6.102 (4.236-9.638)	13.896 (10.236-15.023)	3.03	4	1.02
Spinetoram	100	9.236 (7.563-14.569)	18.626 (16.89-21.545)	2.36	4	0.788

RR = Resistance ratio, determined by dividing the LC_{50} of G4 by LC_{50} of G1population.
LC_{50} lethal concentration that kills 50% of the exposed larvae, Confidence Limit. χ^2 chi-square, n- number of sample.

Table 2. Assessment of cross resistance in *T. absoluta* Madurai population to Cyantraniliprole

Insecticide	n[a]	LC_{50} LCL-UCL (95% confidence limit)	LC_{90} LCL-UCL (95% confidence limit)	χ^2	df	RR
Indoxacarb	100	12.310 (9.400-15.826)	18.960 (15.623-21.360)	3.21	3	1.0
Flubendiamide	100	8.130 (5.630-10.563)	13.287 (11.065-16.530)	5.01	3	1.16
Emamectin benzoate	100	7.704 (6.063-9.426)	10.412 (9.123-11.632)	6.32	3	1.01
Spinosad	100	5.123 (3.692-8.564)	9.563 (7.563-12.369)	5.23	3	0.91
Spinetoram	100	10.153 (8.563-18.623)	19.263 (15.462-24.596)	2.17	3	0.825

RR = Resistance ratio, determined by dividing the LC50 of G4 by LC50 of G1population. LC50 lethal concentration that kills 50% of the exposed larvae, Confidence Limit. $\chi 2$ chi-square.

Table 3. Assessment of cross resistance in *T. absoluta* Salem population to Cyantraniliprole

Insecticide	n[a]	LC_{50} LCL-UCL(95% confidence limit)	LC_{90} LCL-UCL (95% confidence limit)	χ^2	df	RR ratio
Indoxacarb	100	16.00 (15.09016.910)	25.846 (23741-31.076)	1.008	3	1.44
Flubendiamide	100	7.104 (3.013-8.152)	9.955 (6.860-10.331)	5.12	3	1.15
Emamectin benzoate	100	5.427 (5.995-8.426)	11.472 (10.765-13.124)	6.832	3	0.96
Spinosad	100	5.001 (3.214-5.884)	12.933 (12.233-13.966)	1.113	3	1.06
Spinetoram	100	11.071 (8.833-12.907)	15.44 (13.389-23.004)	1.487	3	0.98

RR = Resistance ratio, determined by dividing the LC_{50} of G4 by LC_{50} of G1population..
LC_{50} lethal concentration that kills 50% of the exposed larvae, Confidence Limit. χ^2 chi-square

Table 4. Assessment of cross resistance in *T. absoluta* Kolar population to Indoxacarb

Insecticide	n[a]	LC_{50} LCL-UCL (95% confidence limit)	LC_{90} LCL-UCL (95% confidence limit)	χ^2	df	RR
Cyantraniliprole	120	14.563 (13.256-15.861)	16.105 (15.864-17.145)	6.234	3	1.61
Flubendiamide	120	12.530 (10.531-13.669)	13.014 (12.019-13.912)	8.09	3	1.8
Emamectin benzoate	120	8.721 (6.266-12.337)	12.084 (10.563-13019)	3.982	3	1.0
Spinosad	120	5.788 (4.890-10.619)	10.383 (9.446-10.960)	3.993	3	0.98
Spinetoram	120	10.669 (8..932-14.435)	4.225 (3.803-5.704)	5.258	3	0.90

RR = Resistance ratio, determined by dividing the LC_{50} of G4 by LC_{50} of G1population.

LC_{50} lethal concentration that kills 50% of the exposed larvae, Confidence Limit. χ^2 chi-square, n- sample number.

or similar detoxifying pathways (Wu *et al*., 2014). For example, selection with Cry1Ac in *H. armigera* caused cross-resistance to Cry1Aa and Cry1Ab, which is conferred by cadherin mutations (Xu *et al*., 2005). In the present study, the resistant population showed cross resistance to different insecticides which are sharing same mode of action. Flubendiamide resistant population from Bangalore showed cross resistance to cyantraniliprole and spinosad, cyantraniliprole resistant population from Madurai and Salem showed cross resistance to flubendiamide probably due to both flubendiamide and cyantraniliprole belongs to same mode of action group- IRAC Group 28: Ryanodine Receptor Modulators.

In the present study, the cyantraniliprole resistant population from Madurai and Salem also showed cross resistance to indoxacarb, spinosad and emamectin benzoate. Likewise, the indoxacarb resistant population from Kolar exhibited cross resistance to cyantraniliprole, flubendiamide and emamectin benzoate. Though these insecticides have different mode of action, the cross resistance development may be due to field level exposure of *T. absoluta* to the above mentioned chemicals (Prasannakumar *et al*., 2021). Besides, the pest might have exposed to these insecticides in other tomato growing nearby fields.

The main reason for cross resistance development may be usage of same class of insecticides with similar mode of actions repeatedly by the farmers. Permethrin resistant population of *Spodoptera exigua* (Hübner) had higher cross-resistance (97- and 130-fold, respectively) to cypermethrin and fenvalerate as permethrin and cypermethrin shares the same mode of action i.e IRAC 3A Sodium channel modulators (Che *et al*.,2013). Similarly, azinphosmethyl resistant population of oblique banded leaf roller exhibited cross resistance to benzoyl hydrazine and indoxacarb due to rotation of these insecticides (same MoA) for pest management in field condition (Smirle *et al*., 2002).

Field-collected strain (MR-VL) of the two-spotted spider mite, (*Tetranychus urticae)* Koch, treated with different acaricides exhibited strong resistance to entezine, dimethoate, chlorfenapyr, bromopropylate, amitraz, flucycloxuron and azocyclotin due to its multi-resistant nature and unknown use of chemicals in the distant past (Thomas et al., 2005).The organophosphate-resistant populations of mosquito species showed cross resistance to carbamate and propoxur due to target site insensitivity of AChE as both the compounds have a common target, of acetylcholinesterase (AChE (Ayad and Georghiou, 1975). Repeated application of same insecticides or different insecticides with same MoA hastens the resistant development in insects. Therefore the present study suggests wise use of insecticides with rotation to delay the development of cross resistance in *T. absoluta.*

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