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Bio-efficacy of different insecticides against citrus leaf miner, *Phyllocnistis citrella* infesting sweet orange

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Abstract
A field experiment was carried out to evaluate the different combinations of insecticides against leaf miner, *Phyllocnistis citrella* infesting sweet orange during 2017 at Horticultural Research Station, Junagadh Agricultural University, Junagadh. Based on pooled over periods over sprays, leaf miner can be effectively managed by spinosad 45 SC (14.42%) and imidacloprid 17.8 SL (16.11%) were found most effective insecticide against this pest. While, the combination of deltamethrin + triazophos 36 EC (20.10%) followed by emamectin benzoate 5 SG (21.46%) and diafenthiuron 50 WP (22.90%) were found less effective in the control of the pest whereas, thiodicarb 75 WP (25.28%), dichlorvos 76 EC (27.37%), chlorpyriphos 20 EC (28.61%) and cartap hydrochloride 75 WG (29.01%) performed less in giving satisfactory protection to citrus crop due to *P. citrella.*

Keywords: Leaf miner, *Phyllocnistis citrella*, chemical control, sweet orange

Introduction
The word "citrus" is derived from the ancient Greek *Kedros* and Latin *Cedrus*. The sweet orange, *Citrus sinensis* is the fruit of the citrus in the family Rutaceae. As of 1987, orange trees were found to be the most cultivated fruit tree in the world and are widely grown in tropical and subtropical climates for their sweet fruit. The fruit of the orange tree can be eaten fresh or processed for its juice or fragrant peel. Among the different citrus trees, sweet orange occupies number one position in production in the world by accounting for about 70 per cent of the total production (Anon., 2012). Brazil, Florida (USA), and China are the three largest sweet orange producers. Fruits of Sweet orange have very tight peel and are classified into the hard-to-peel group. They are often used for juice processing, rather than fresh consumption. The tree gave its best in fertile soil having pH range of 5.5 to 7.5 with adequate rainfall /irrigation in tropical and sub-tropical climates and area having rainfall up to 500 mm to hilly area having 2500 mm. Among different citrus fruits, pulp of orange is an excellent source of vitamin C and provides 64 per cent/100 g serving of daily value. These oranges contains diverse phyto-chemicals *viz.*, carotenoids (beta-carotene, lutein and beta-cryptoxanthin) and flavonoids (e.g. naringenin) (Aschoff *et al.*, 2015) [23] with numerous volatile organic compounds which produces orange aroma, including aldehydes, esters, terpenes, alcohols, and ketones (Perez-Cacho and Rouseff, 2008) [6]. Flavor of oranges are vary from sweet to sour and commonly peeled and eaten fresh or squeezed for juice. Apart from main pulp, thick bitter rind is to be discarded, but can be processed into animal feed by desiccation. It is also been used in certain recipes as a food flavoring or garnish. The outermost layer of the rind can be thinly grated with a zester to produce orange zest. Zest is popular in cooking because it contains oils and has a strong flavor similar to that of the orange pulp. The white part of the rind, including the pith, is a source of pectin and has nearly the same amount of vitamin-C as the flesh and other nutrients. Although not as juicy or tasty as the flesh, orange peel is edible and has significant contents of vitamin-C, dietary fiber, total polyphenols, carotenoids, limonene and dietary minerals, such as potassium and magnesium (Barros *et al*., 2012) [4]. In the situation of global climate change, living organisms are changing their living habitat as well as style which directly affect their span of life. A dominant animal, insect, have capacity to change their behavior and habitat with the changing of the environment and so, it was necessary to see the impact of changing pattern in abiotic factors on sweet orange leaf miner.

Several chemical pesticides have been recommended for combating leaf miner. However, problems like residues in fruits, pulps and environmental contamination are the result of injudicious use of chemical pesticides. Such reliance on insecticides has created many problems such as very frequent application of insecticides, excessive residues on market that concerns general consumer health and the environment, pesticide resistance, trade implications, poisoning, hazards to non-target organisms, increased production costs etc. Among the several avenues to overcome the insecticidal resistance problem and as this pest is attacking more in primary stage of the crop, to check the effect of new molecules of insecticides was one of the important considerations.

Material and Method

The experiment was conduct to study the bio-efficacy of different insecticides against leaf miner, the experiment was laid out in a Completely Randomized Design with three repetition having plot size of one tree as one repetition during 2016-17 at Horticultural Instructional farm, College of Agriculture, Junagadh Agricultural University, Junagadh. The same aged trees of citrus (variety "*Pawli Chap*") were selected, which was grown at distance of 6 m x 6 m.Three trees of citrus as three repetitions per treatment was selected and tagged. Total 30 trees were selected for the purpose. Ten young shoots per tree were selected from different direction of the tree and tagged. From each shoot, number of leaf and leaf having live citrus leaf miner larvae was marked. For insecticidal application, formulation of various insecticides at various doses was prepared. The spray was carried out by foot sprayer. The sprayer was cleaned thoroughly before subsequent application of insecticides. Water spray was given in untreated control. The spray was carried out in August to December when the pest population reaches to its peak. Three sprays were given at every 40 days interval. In order to evaluate different insecticides against citrus leaf miner, observations were taken on leaf miner damage were recorded at 7, 14, 21 and 28 days after each spray. Further, obtained data was converted into per cent reduction of leaf miner over control through following formula (Abbott, 1925) [1].

$$\text{Per cent reduction over control} = 100 \times \frac{C - T}{C}$$

Where

T= per cent damage of leaf miner from treated Plot
C= per cent damage of leaf miner from controlled Plot

Result and Discussion

The results showed that the infestation of leaf miner after pooled over periods over sprays are presented in (Table 1) and results revealed that all the treatments were recorded significantly lower damage in the range of [14.42 to 29.01%] than control [33.55%] recorded. The order of insecticidal treatments in comparison to control based on leaf miner infestation on citrus damage due to, *P. citrella* given in bracket was: spinosad 45 SC (14.42%) <imidacloprid 17.8 SL (16.11) <deltamethrin + triazophos 36 EC (20.10) <emamectin benzoate 5 SG (21.46) <diafenthiuron 50 WP (22.90) <thiodicarb 75 WP (25.28) <dichlorvos 76 EC (27.37) <chlorpyriphos 20 EC (28.61) <cartap hydrochloride 75 WG (29.01) < control (33.55), respectively.

Among the tested insecticides, spinosad was found significantly superior treatments as it has recorded lowest per cent infestation during all three spray with pooled over period over spray [14.42] to the rest of the treatments and it was found at par with imidacloprid [16.11%]. The next best treatments were deltamethrin + triazophos [20.10%], emamectin benzoate [21.46], diafenthiuron [22.90], thiodicarb [25.28] and dichlorvos [27.37] as they were at par with each other. At the other side, dichlorvos was found at par with chlorpyriphos [28.61] and cartap hydrochloride [29.01].

As far as the percent reduction over control, spinosad recorded highest reduction of *P. citrella* population (36.69%) followed by imidacloprid (33.16%). Among the rest of the treatments, deltamethrin + triazophos, emamectin benzoate and diafenthiuron were recorded 19.04 to 24.55 percent reduction over control and found mediocre in their effectiveness. While, thiodicarb, dichlorvos, chlorpyriphos and cartap hydrochloride found least effective insecticides as they have recorded 7.79 to 14.69 percent reduction over control.

In all, *P. citrella* can effectively be managed by spray application of spinosad and imidacloprid. deltamethrin + triazophos, emamectin benzoate and diafenthiuron was found less effective in the control of the pest while, thiodicarb, dichlorvos, chlorpyriphos and cartap hydrochloride did not perform better in giving satisfactory protection to citrus crop due to *P. citrella.* The obtained results are in close conformity with the earlier workers i.e. spinosad 45 SC (0.03%) was found best treatment for the control of citrus leaf miner (7.23%) followed by imidacloprid 17.8 SL (8.52%) [Shinde *et al*., 2017] [7]. According to Mohamed and Abdalla (2015) [5], spinosad 480 SC proved the best significant results on lemon seedlings for two weeks against the leaf miner. In the present investigation, more or less same trend was also observed. However, no information is available on rest of the insecticides evaluated in the present investigation and hence, results could not be compared with the work done in past.

Table 1: Impact of different insecticides on leaf miner population after each spray

Treatments	Infestation of leaf miner (%)			
	Pooled over periods			Pooled over period over spray
	1st spray	2nd spray	3rd spray	
Dichlorvos 76 EC	31.34 (27.07) [6.25] def	32.19 (28.40) [12.69] d	31.04 (26.64) [13.20] ef	31.52 (27.37) [10.71] ef
Chlorpyriphos 20 EC	31.66 (27.57) [5.30] ef	33.00 (29.70) [10.52] d	32.27 (28.56) [9.82] f	32.31 (28.61) [8.54] f
Cartap hydrochloride 75 WG	31.93 (27.99) [4.50] ef	33.19 (29.99) [10.01] d	32.59 (29.07) [8.87] fg	32.57 (29.01) [7.79] f
Deltamethrin + Triazophos 36 EC	26.83 (20.39) [19.75] b	26.52 (19.96) [28.11] b	26.49 (19.95) [25.80] bc	26.61 (20.10) [24.55] b
Emamectin benzoate 5 SG	27.61 (21.50) [17.41] bc	27.38 (21.18) [25.81] b	27.77 (21.72) [22.31] cd	27.59 (21.46) [21.84] bc
Thiodicarb 75 WP	29.58 (24.40) [11.52] cde	30.63 (25.98) [17.00] cd	30.23 (25.46) [15.56] def	30.15 (25.28) [14.69] de
Diafenthiuron 50 WP	28.80 (23.22) [13.87] bcd	29.00 (23.53) [21.34] bc	27.91 (21.95) [21.93] cde	28.57 (22.90) [19.04] cd
Imidacloprid 17.8 SL	23.45 (15.92) [29.84] a	23.78 (16.30) [35.59] a	23.60 (16.12) [34.06] ab	23.61 (16.11) [33.16] a
Spinosad 45 SC	22.90 (15.16) [31.48] a	21.94 (13.98) [40.51] a	22.07 (14.14) [38.14] a	22.30 (14.42) [36.69] a
Control	33.43 (30.38)f	36.91 (36.09)e	35.76 (34.19)g	35.37 (33.55)g
ANOVA				

S.Em. +	P	0.25	0.25	0.19	0.40
	S	-	-	-	0.12
	T	0.40	0.40	0.47	0.39
	PxS	-	-	-	0.24
	PxT	0.79	0.81	0.94	0.50
	SxT	-	-	-	0.43
	PxSxT	-	-	-	0.85
C. D. at 5 %	P	NS	NS	0.66	NS
	S	-	-	-	NS
	T	1.13	1.15	1.33	1.15
	PxS	-	-	-	0.69
	PxT	NS	NS	NS	1.36
	SxT	-	-	-	1.18
	PxSxT	-	-	-	NS
C.V %		4.49	4.79	5.55	5.10

Notes:
1. NS: Non-significant
2. Figures in parentheses outside arcsine value and () are retransformed values, while figures in parentheses [] are per cent reduction over control, arcsine transformation

Summary and Conclusion

It is concluded from the present investigation that the spinosad 45 SC was found significantly superior treatments as it has recorded lowest per cent infestation [14.42] to the rest of the treatments and it was found at par with imidacloprid 17.8 SL [16.11%]. The next best treatments were deltamethrin + triazophos 36 EC [20.10%], emamectin benzoate 5 SG [21.46%], diafenthiuron 50 WP [22.90%], thiodicarb 75 WP [25.28%] and dichlorvos 76 EC [27.37%] as they were at par with each other. At the other side, dichlorvos 76 EC was found at par with chlorpyriphos 20 EC [28.61%] and cartap hydrochloride 75 WG [29.01%]. As far as the percent reduction over control, spinosad 45 SC recorded highest reduction of *P. citrella* population (36.69%) followed by imidacloprid 17.8 SL (33.16%). Among the rest of the treatments, deltamethrin + triazophos36 EC, emamectin benzoate 5 SG and diafenthiuron 50 WP were recorded between 19.04 to 24.55 percent reduction over control and found mediocre in their effectiveness. While, thiodicarb 75 WP, dichlorvos 76 EC, chlorpyriphos 20 EC and cartap hydrochloride 75 WG found least effective insecticides as they have recorded 7.79 to 14.69 percent reduction over control.

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