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HOST PREFERENCE, SPATIAL DISTRIBUTION AND CHEMICAL CONTROL OF THE CITRUS LEAFMINER, *Phyllocnistis citrella* STAINTON (LEPIDOPTERA: GRACILLARIIDAE)

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ABSTRACT: The citrus leafminer (CLM), *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) is one of the most serious pests of nursery as well as young plantations of citrus. The present work aimed to study host preference, spatial distribution within the tree's canopy and chemical control of CLM in citrus orchard located at Inshas District, Sharkia Governorate, Egypt. The obtained results indicated that CLM significantly preferred to attack navel orange and eureka lemon more than valencia orange, mandarin, baladi orange and bitter orange. This preference of CLM to navel orange may be attributed to the highly contents of carbohydrates, nitrogen, phosphorus, potassium, iron, protein and ascorbic acid in navel orange leaves in comparison with the other tested hosts. On the contrary, bitter orange was the lowest preferred host to CLM because of its lowest content of nitrogen, phosphorus, potassium, protein and humidity. On the other hand, the present results showed that CLM highly distributed in west direction more than the other directions and center of host trees during spring season. With respect to control of CLM, the obtained results showed that KZ oil was the most effective compound in controlling CLM infesting navel orange trees; while, lambda, super misrona, diver, albolium and abamectin exhibited moderate ranks in controlling CLM. Acetamipride was the least effective insecticide.

Key words: *Phyllocnistis citrella*, citrus leafminer, host preference, spatial distribution, chemical control.

INTRODUCTION

Citrus are of the most important fruit crops in Egypt. The cultivated area of citrus trees is more than 340000 faddans. This area has been rapidly increased specially in newly reclaimed lands. The citrus leafminer (CLM), *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) is one of the most serious pests of nursery and young plantations as well as new flushes of citrus trees causing severe damage to them (**Heppner, 1993; Heppner and Dixon, 1995; Smith and Hoy, 1995**). It is native to subtropical and tropical Asia (**CABI, 1986**) and was detected in Egypt during summer 1994 attacking many citrus orchards and nurseries (**Hashem, 1996**). It occurs all the year round and attacks more than half of the new leaves produced on citrus trees (**Wilson, 1991**). Females of CLM deposit eggs singly on the adaxial and abaxial sides of young leaves (**Knapp *et al.*, 1995**). Four consecutive larval instars feed in the leaf parenchyma, finally forming a pupal chamber from which the adult leafminer emerges. Larvae feed in the mesophyll beneath the leaf epidermis, ingesting the sap and producing a chlorotic leaf patch on a variety of citrus cultivars and many related species in family: Rutaceae including some ornamental plants (**Knapp *et al.*, 1995; Jacas *et al.*, 1997**). This pest is a multivoltine species, with total generation time fluctuating between 13 and 52 days depending on temperature (**Knapp *et al.*, 1995**) and has eleven annual generations (**Abdel-Rahman, 1998**).

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Citrus nurseries are especially susceptible to CLM damage because seedlings and young trees flush nearly continuous (**Villanueva-Jimenez and Hoy, 1998**). The damage is directly related to the ratio of the young leaves and the total canopy of the young trees (**Argov and Rossler, 1998)**. CLM may prevent young leaves from expanding causing them to remain curled and twisted (**Legaspi *et al*., 1999)**. According to **Giorbelidze (1979)** and **Argov and Rossler (1998)**, CLM attacks succulent stems and fruits in some citrus varieties (especially pomelo) which become deformed and yield poor fruits and reduces the marketability of infested fruits. As a result of direct damage caused by CLM feeding activity, growth can be slowed on young trees and the yield can be reduced in mature trees (**Pena *et al*., 2000**). After CLM has finished feeding, other insects such as aphids and mealybugs often continue feeding on the damaged area (**Michaud and Grant, 2003**). In addition, CLM can augment the severity of citrus canker, *Xanthomonas citri* Dowson and other fungus pathogens such as *Alternaria* on damaged leaf plants (**Sohi and Sandhu, 1968; Guerout, 1994; Achor *et al*., 1997; Bautista-Martinez *et al*., 1998**). So, if CLM is not controlled, it may cause total defoliation.

Host preference of CLM was studied in Florida, Australia, Ecuador, Egypt and Argentina by **Wilson (1991)**, **Heppner (1993)**, **Bermudez *et al.* (2004)**, **Elkady (2005)**, **El-Dessouki *et al.* (2005) and Goane *et al.* (2008)**; they mentioned that grapefruit and orange as the most preferred cultivars for CLM with severe damages being also reported on lime and grapefruit in Florida (**Knapp *et al*., 1995). Martin *et al.* (2005), Videla *et al.* (2006) and Goane *et al.* (2008)** added that abundance of CLM differs between cultivars, but variations in host use as indicated by infestation levels may result from differences in either herbivore preference or performance.

Autumn season is the main control season against CLM in the Egyptian fields, because CLM severely attacks the autumn flushes. In order to achieve a good control of CLM, ecological studies should be done. So, the aims of this study were as follows:

1) Evaluation the preference of CLM to six citrus hosts under field conditions and correlation of this preference with the chemical content of the leaves.
2) Studying of the spatial distribution of CLM within the canopy of its host trees.
3) Investigation of the effectiveness of certain insecticides against CLM under field conditions.

MATERIALS AND METHODS

The present experiments were conducted in a citrus orchard located at Inshas District, Sharkia Governorate, Egypt. This orchard was cultivated by six citrus host species/varieties of the citrus leafminer (CLM), *Phyllocnistis citrella* Stainton; these hosts were navel orange, valencia orange, bitter orange, baladi orange, mandarin and eureka lemon.

Host Preference and Spatial Distribution of CLM Within the Canopy of Host Trees

Twice monthly samples were collected during spring months (April, May and June) of 2017. Ten trees (as replicates) of each host species/varieties homogeneous in size and age were selected for this experiment. Twenty five of the newly leaf flushes were randomly collected from each tree. These leaves were collected from the different cardinal directions (north, south, east and west) in addition to center of each tree (five leaves per direction). The collected leaves from each direction were kept separately inside paper bags and well tied; then they were taken to laboratory for examination. CLM larvae were examined carefully by aid of a binocular stereoscope microscope. Number of alive larvae and infestation as serpentine mines percentage of CLM were calculated and recorded in each host species/varieties at different directions of trees.

Chemical Analyses of the Tested Host Plant Leaves

To explain the relation between leaf components and CLM preference to its host species/ varieties, certain components of navel orange, valencia orange, bitter orange, baladi orange, mandarin and eureka lemon leaves were determined. The determined components in these leaves were those of nitrogen, phosphorus, potassium, calcium, zinc, iron, manganese, total sugars, glucose, acidity, protein, carbohydrates, fibers, ash, dry weight, humidity, TSS, ascorbic acid and beta carotene. Chemical analyses were done in Horticultural Research Institute, Agricultural Research Center, Ministry of Agriculture, Egypt.

Control of CLM

Used insecticides

Seven insecticides were used namely:

a) Lambda cyhalothrin (Catron 5% EC).

b) Abamectin (Nasractine 1.8 EC).

c) Acetamipride (Mospilan 20% SP).

d) Albolium (Petrolerum oil, mayonasie 80%).

e) KZ oil (Mineral oil 95%, EC).

f) Super misrona (Mineral oil 94% EC).

g) Diver (Mineral oil 97% EC) .

Field experiments

The experiments were carried out during autumn 2016 and spring 2017 (the highest periods of the newly leaf and stem flushes) on the most preferred host plant (navel orange) at the previously mentioned orchard. An experimental area was divided into eight sections of 24 plots, each plot consisted of four trees. The plots were done by using complete blocks randomized design with three replicates for each treatment. Trees were treated once with all insecticides as foliar spray in 21 plots (seven insecticides with three replicates). The other three plots were taken without any insecticides treatment to be used as control.

To evaluate the effectiveness of the tested insecticides, samples of 25 leaves were picked up representing the different directions of tree from each replicate (plot) just before spraying in addition to 1, 3, 5, 7, 9, 11 and 14 days after spraying. Samples were placed in paper bags and transferred immediately to the laboratory for examination. Alive larvae of CLM were counted and recorded. The reduction percentages in CLM larvae resulted from the applications of the tested sprayed insecticides were calculated according to **Henderson and Tilton (1955)**.

Statistical Analysis

Data were statistically analyzed according to Duncan's Multiple Range Test (**Costata, 2004**). In addition to the correlation and regression analyses were done by using **Cosatat (2004)**.

RESULTS

Host Preference of CLM

Results presented in Fig. 1 show that the newly tender leaves of both navel orange and eureka lemon were insignificantly invaded by the highest mean numbers of *P. citrella* larvae (6 and 5.4 larvae/sample, respectively). But, the two previous species significantly differed with the other tested species/varieties (valencia orange, mandarin, baladi orange and bitter orange) which insignificantly harboured low mean numbers of CLM larvae/25 newly vegetative leaves of 2.8, 1.6, 1.5 and 1.4, respectively. These results indicated that both navel orange and eureka lemon were more preferable for CLM than the other tested hosts. Also, the means of infestation percentages on these hosts were 21.0, 18.8, 10.2, 6.5, 5.3 and 5.2%, respectively.

Results compiled in Table 1 show the chemical contents of different components in navel orange, eureka lemon, valencia orange, mandarin, baladi orange and bitter orange leaves.

As shown in Fig. 1 and Table 1, the preference of CLM to navel orange and eureka lemon may be attributed to their highly content of carbohydrates in comparison with the other tested hosts; however the percentage of carbohydrates in navel orange and eureka lemon were 37.5 and 40.7%. Also, navel orange (the most preferred host) had the highest contents of nitrogen (1.96%), phosphorus (0.79%), potassium (2.66%), iron (86.0 ppm), protein (12.25%) and ascorbic acid (33.21 mg/100g). On the contrary, navel orange had the lowest content of glucose (25.1 mg).

With respect to bitter orange, which was the lowest prefered (Fig. 1), this behavior may be attributed to the lowest content of nitrogen (1.40%), phosphorus (0.63%), potassium (1.82%), protein (8.75%) and humidity (83.2%) in bitter orange leaves (Table 1). On the contrary, bitter orange leaves had the highest content of zinc (27.6 ppm), beta carotene (8.8%) and dry weight (16.8%).

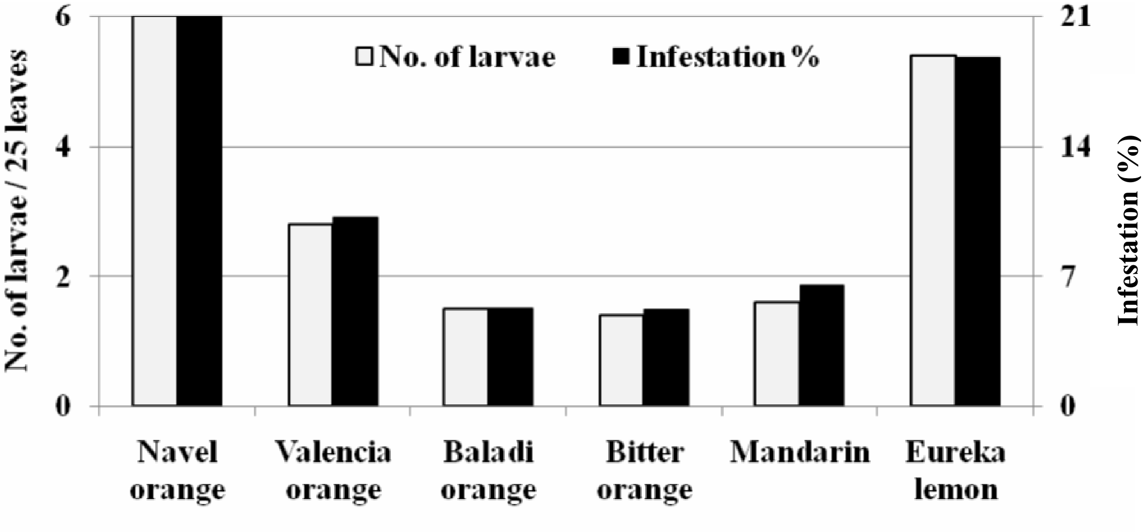

Fig. 1. **Mean number of larvae/25 leaves and infestation percentages of CLM in navel orange, valencia orange, baladi orange, bitter orange, mandarin and eureka lemon orchards at Inshas Districts, Sharkia Governorate (for larval population: $LSD_{(P=5\%)}$ = 2.1, F = 8.4 and P = 0.000 and for infestation%: $LSD_{(P=5\%)}$ = 7.0, F = 8.7 and P = 0.000)**

Table 1. Chemical analyses of navel orange, valencia orange, baladi orange, bitter orange, mandarin and eureka lemon leaves at Inshas Districts, Sharkia Governorate, during 2016 season

Leaf content	Navel orange	Valencia orange	Baladi orange	Bitter orange	Mandarin	Eureka lemon
N (%)	1.96	1.50	1.76	1.40	1.47	1.41
P (%)	0.79	0.70	0.76	0.63	0.65	0.59
K (%)	2.66	2.09	2.30	1.82	1.95	1.85
Ca (%)	1.13	0.93	0.97	0.96	0.91	1.21
Zn (ppm)	26.4	23.3	25.3	27.6	23.9	29.4
Fe (ppm)	86.0	62.2	81.6	77.7	85.4	61.7
Mn (ppm)	56.7	50.7	52.8	63.2	49.4	67.8
Total sugars (%)	3.90	3.36	3.67	2.96	3.15	2.86
Glucose (mg)	25.1	25.6	25.4	26.0	25.8	26.2
pH (%)	2.51	2.40	2.49	2.90	2.46	3.06
Protein (%)	12.25	9.37	11.03	8.75	9.19	8.81
Carbohydrates (%)	37.5	27.7	31.9	35.1	23.9	40.7
Fibers (%)	21.5	18.9	23.1	19.4	17.2	20.5
Ash (%)	15.8	13.1	17.2	13.5	12.8	14.8
Dry weight (%)	14.9	13.8	15.1	16.8	12.6	16.5
Humidity (%)	85.2	86.2	84.9	83.2	87.4	83.5
TSS (%)	3.79	3.40	3.56	5.30	3.19	5.45
Ascorbic acid (mg/ 100g)	33.21	28.45	31.55	25.71	26.10	23.19
Beta carotene (%)	7.2	7.5	6.9	8.8	9.0	8.3

Results presented in Table 2 show that population size and infestation percentages of CLM exhibited adversely responses to amounts of iron, glucose, humidity and beta carotene in its host species/varieties; however, there were negative correlations between both of population size and infestation percentage. On the contrary, population size and infestation percentage exhibited directly responses to amounts of all other determined components in its host species/varieties; however, there were positive correlations between them.

With respect to regression coefficient value, as shown in Table 2, it recorded the highest value with calcium. This means that each increase of calcium by one percentage increased CLM population size by 15.24 larvae per 25 leaves and increased infestation percentage by 50.67%. Contrarily, the lowest regression coefficient was recorded with iron; however, each increase of iron concentration by one part per million (ppm) decreased the pest population by 0.04 larvae/ 25 leaves and decreased infestation percentage by 0.13%.

On the another hand, calcium percentage had the highest effective determined component on CLM population and its infestation percentage; where, the determination coefficient values (R^2) were 80.2 and 77.5%, respectively. Carbohydrates percentage followed calcium in its effect on CLM population and infestation (R^2 = 46.3 and 43.2%). Zinc content had the third rank affecting CLM population (R^2 = 23.2%) and infestation (R^2 = 20.8%) followed by manganese (R^2-values were 20.1 and 17.8%) and potassium (R^2-values were 16.7 and 18.1%, respectively). Both ascorbic acid and phosphorus in host leaves exhibited the lowest effect on CLM activity; however, the determination coefficient values (R^2) on CLM population were 1.1 and 1.2%; while, those on infestation percentage were 1.4 and 1.6%, respectively (Table 2).

Distribution of CLM Within Canopy of Host Trees

Distribution of CLM larvae and infestation percentages within the different cardinal directions and center of navel orange, valencia orange, baladi orange, bitter orange, mandarin and eureka lemon is illustrated in Tables 3 and 4.

As shown in these tables, number of CLM larvae and infestation percentages were the highest in west direction in case of navel orange, valencia orange and bitter orange; while, center of these trees had the lowest mean number of CLM and infestation percentages with significant differences between these directions. With respect to baladi orange, mandarin and eureka lemon, there were no significant differences between population sizes or infestation percentages in the different cardinal directions and center of CLM host- trees with the exception of those in respect of both west and south directions in case of balady orange which proved to be statistically significant.

On the another hand, navel orange and eureka lemon had significantly high CLM activity (population size and infestation percentage) in the different tree directions with no significant differences between these hosts. While, valencia orange, baladi orange, bitter orange and mandarin had the second rank of CLM activity at the tree cardinal directions with no significant differences between them, but they were significantly less than that of navel orange and eureka lemon (Tables 3 and 4).

Control of CLM

During autumn season

Results presented in Table 5 show that the mean number of CLM irregularly decreased after treatment with all examined insecticides. The decrement lasted about 9 days in case of all insecticides. The general mean numbers of CLM larvae/sample were 12.0, 13.6, 13.9, 5.2, 11.8, 5.5 and 8.6 in case of lambda, abamectin, acetamipride and mineral oils of KZ oil, albolium, super misrona and diver, respectively, compared to the untreated one (control) which was significantly higher (26.3 larvae/sample) than that of the tested insecticides.

As shown in Table 6, reduction percentages in numbers of CLM larvae in navel orange orchard caused by lambda, abamectin, acetamipride, KZ oil, albolium, super misrona and diver reached 50.8, 47.8, 42.9, 78.3, 57.6, 76.6 and 64.6%, respectively as residual reduction percentages; while, the initial reduction percentages for these treatments were 95.9, 81.4, 78.9, 96.0, 76.8, 90.2 and 72.0%, respectively.

Table 2. Simple correlation and regression between citrus leafminer (population and infestation %) and plant leaf contents among the tested host plant species/varieties at Inshas District, Sharkia Governorate

Leaf content	Population				Infestation (%)			
	r	b	P	R^2	r	b	P	R^2
N (%)	0.37	3.39	0.471	13.6	0.38	11.89	0.453	14.7
P (%)	0.11	3.00	0.835	1.2	0.13	11.45	0.811	1.6
K (%)	0.41	2.64	0.421	16.7	0.43	9.31	0.400	18.1
Ca (%)	0.90	15.24	0.016	80.2	0.88	50.67	0.021	77.5
Zn (ppm)	0.48	0.43	0.333	23.2	0.46	1.39	0.363	20.8
Fe (ppm)	-0.24	-0.04	0.652	5.6	-0.21	-0.13	0.687	4.5
Mn (ppm)	0.45	0.13	0.373	20.1	0.42	0.40	0.405	17.8
Total sugars (%)	0.19	1.00	0.711	3.8	0.21	3.66	0.686	4.5
Glucose (mg)	-0.15	-0.80	0.769	2.4	-0.18	-3.08	0.738	3.1
pH (%)	0.27	2.06	0.604	7.3	0.24	6.24	0.643	5.9
Protein (%)	0.36	0.53	0.478	13.3	0.38	1.87	0.460	14.3
Carbohydrates (%)	0.68	0.23	0.137	46.3	0.66	0.74	0.156	43.2
Fibers (%)	0.27	0.27	0.610	7.1	0.25	0.84	0.638	6.1
Ash (%)	0.25	0.30	0.631	6.3	0.24	0.96	0.652	5.6
Dry weight (%)	0.24	0.31	0.651	5.6	0.21	0.91	0.695	4.3
Humidity (%)	-0.22	-0.29	0.676	4.8	-0.19	-0.83	0.720	3.6
TSS (%)	0.26	0.55	0.616	6.9	0.23	1.66	0.654	5.5
Ascorbic acid (mg/100g)	0.10	0.06	0.846	1.1	0.12	0.22	0.822	1.4
Beta carotene (%)	-0.26	-0.60	0.622	6.6	-0.25	-2.00	0.629	6.4

Notes: r = Correlation coefficient. b = Regression coefficient.
P = Significance of correlation and regression coefficients. R^2 = Determination coefficient.

Table 3. Spatial distribution of citrus leafminer larvae in different host-trees at Inshas District, Sharkia Governorate

Host plant	North	South	East	West	Center	Avg.	LSD	F	P
Navel orange	4.4±1.1	8.1±2.8	6.7±2.4	9.0±3.0	1.6±1.1	5.96	2.4	12.7	0.000
Valencia orange	1.7±1.1	3.4±1.9	3.3±1.4	4.7±2.1	0.9±0.7	2.80	1.7	7.1	0.000
Baladi orange	1.0±1.1	2.3±1.8	1.4±1.4	2.0±1.1	0.6±0.8	1.46	1.4	2.2	0.088
Bitter orange	1.1±1.3	1.0±0.7	0.6±0.9	3.8±3.1	0.4±0.5	1.38	1.8	3.7	0.022
Mandarin	1.6±1.3	1.3±1.2	1.7±1.4	1.6±0.5	2.0±1.4	1.64	1.3	0.3	0.863
Eureka lemon	4.4±2.9	4.4±3.2	7.3±3.3	6.4±4.1	4.7±3.9	5.44	3.9	1.0	0.440
Average	2.37	3.42	3.50	4.58	1.70	----	----	----	----
LSD $_{(P=5\%)}$	1.8	2.4	2.2	2.8	2.0	----	----	----	----
F	6.7	9.8	13.1	8.0	4.9	----	----	----	----
P	0.000	0.000	0.000	0.000	0.002	----	----	----	----

Table 4. Spatial distribution of infestation percentages of citrus leafminer in different host-trees at Inshas District, Sharkia Governorate

Host plant	North	South	East	West	Center	Avg.	LSD	F	P
Navel orange	16.0±3.3	27.4±6.3	24.6±5.9	30.9±7.9	6.3±4.5	21.04	6.3	20.5	0.000
Valencia orange	6.9±4.5	12.0±7.3	13.1±5.5	15.4±5.9	3.4±2.8	10.16	5.9	5.8	0.001
Baladi orange	3.5±4.3	8.7±6.7	4.0±3.3	8.0±4.6	2.3±3.1	5.30	5.0	2.6	0.050
Bitter orange	4.7±5.2	3.9±2.8	2.4±3.6	13.6±9.2	1.6±2.2	5.24	5.8	4.2	0.012
Mandarin	6.3±5.1	5.1±5.0	6.9±5.5	6.3±2.1	8.0±5.7	6.52	5.3	0.3	0.863
Eureka lemon	14.9±8.6	16.0±9.8	24.0±9.5	22.3±13.2	16.6±11.4	18.76	11.6	1.0	0.400
Average	8.72	12.18	12.50	16.08	6.37	----	----	----	----
LSD $_{(P=5\%)}$	5.9	7.4	6.5	8.6	6.5	----	----	----	----
F	6.6	10.7	17.6	9.5	5.8	----	----	----	----
P	0.000	0.000	0.000	0.000	0.001	----	----	----	----

Table 5. Effect of the tested compounds against citrus leafminer larvae in navel orange orchard at Inshas District, Sharkia Governorate during autumn season of 2016

Treatment	No. before treatment	Mean no. of CLM larvae after treatment (in days)							
		1	3	5	7	9	11	14	Avg.
Lambda	26.0±1.0	1.0±0.0	4.0±2.0	9.0±1.0	9.7±1.5	15.3±1.5	21.7±1.5	23.3±1.5	12.0
Abamectin	26.7±1.5	4.7±1.5	6.3±1.5	7.7±1.5	11.0±1.0	17.3±1.5	23.3±1.5	24.7±1.5	13.6
Acetamipride	25.0±2.0	5.0±1.0	7.0±1.0	8.7±1.5	13.3±1.5	17.7±1.5	23.3±2.1	22.3±1.5	13.9
KZ oil	26.3±2.1	1.0±0.0	2.3±1.5	5.0±2.0	0.0±0.0	0.0±0.0	5.0±1.0	23.0±1.7	5.2
Albolium	27.3±1.5	6.0±2.0	5.0±1.0	3.3±1.5	2.0±1.0	16.7±1.5	24.0±2.0	25.3±1.5	11.8
Super misrona	24.7±1.5	2.3±1.5	2.7±1.5	6.7±1.5	0.0±0.0	0.0±0.0	7.0±1.0	19.7±1.5	5.5
Diver	23.7±2.1	6.3±1.5	5.0±1.0	9.3±1.5	1.0±0.0	5.0±1.0	14.7±1.5	18.7±1.5	8.6
Control	25.0±1.0	23.7±1.5	24.0±1.0	26.7±1.5	23.7±1.5	33.0±2.0	28.0±2.0	25.3±2.5	26.3
LSD $_{(P=5\%)}$	2.84	2.31	2.37	2.67	1.83	2.31	13.25	5.37	2.29
F	1.61	90.41	79.31	65.92	189.4	206.0	1.40	1.36	76.38
P	0.283	0.000	0.000	0.000	0.000	0.000	0.272	0.288	0.000

Table 6. Reduction percentage of citrus leafminer larvae caused by the tested compounds in navel orange orchard at Inshas District, Sharkia Governorate during autumn season of 2016

Treatment	Initial effect	Reduction (%) of CLM larvae after treatment (in days)						Mean residual effect (%)	General effect (%)
		3	5	7	9	11	14		
Lambda	95.9	84.0	67.6	60.6	55.4	25.5	11.4	50.8	73.4
Abamectin	81.4	75.4	73.0	56.5	50.9	22.1	8.6	47.8	64.6
Acetamipride	78.9	70.8	67.4	43.9	46.4	16.8	11.9	42.9	60.9
KZ oil	96.0	90.9	82.2	100	100	83.0	13.6	78.3	87.1
Albolium	76.8	80.9	88.7	92.3	53.7	21.5	8.4	57.6	67.2
Super misrona	90.2	88.6	74.6	100	100	74.7	21.2	76.6	83.4
Diver	72.0	78.0	63.3	95.5	84.0	44.6	22.0	64.6	68.3

The general mean percentages of reduction caused by lambda, abamectin, acetamipride, KZ oil, albolium, super misrona and diver were 73.4, 64.6, 60.9, 87.1, 67.2, 83.4 and 68.3%, respectively. The tested insecticides could be arranged in a descending order according to the percentages of reduction in infestation as follows: KZ oil, super misrona, lambda, diver, albolium, abamectin and acetamipride, respectively (Table 6).

During spring season

Results tabulated in Table 7 show that all the tested pesticides significantly decreased the larval population of CLM in an irregular way compared to the untreated control. Results also cleared that all insecticides caused satisfactory decrease till the 11th day after treatment. The general mean numbers of CLM were 10.4, 10.1, 12.1, 6.1, 11.3, 7.3 and 8.7 larvae/sample for lambda, abamectin, acetamipride, KZ oil, albolium, super misrona and diver, respectively. On the other hand, the general mean numbers of CLM in control treatment was 24.8 larvae/ sample.

Results presented in Table 8 indicate that the mean reduction percentages of CLM population on navel orange plants after 24 hr. caused by lambda, abamectin, acetamipride, KZ oil, albolium, super misrona and diver were 100, 94.5, 75.5, 75.5, 74.2, 75.4 and 85.8%, respectively. On the other hand, the mean reduction percentages of residual effect were 54.9, 41.8, 36.6, 71.6, 56.4, 68.8 and 58.1%, respectively. While, the mean percentages of accumulation effect (general effect) were 77.5, 73.6, 72.1, 72.0, 68.1, 65.3 and 56.1% for lambda, KZ oil, super misrona, diver, abamectin, albolium and acetamipride, successively.

DISCUSSION

The present results showed that the preference of *P. citrella* varied among citrus host species/ varieties. However, navel orange was the most preferred host plant to CLM followed by eureka lemon; while, bitter orange, baladi orange and mandarin were the lowest preferred host plants to this pest. Valencia orange had a moderate rank in CLM host plant preference between the tested host plant species/ varieties. These results agree with the findings of **Elkady (2005)**; who reported that navel orange was more susceptible to CLM infestation in comparison with mandarin. The same author added that lemon was the most preferred host plant to CLM. Also, **El-Dessouki *et al.* (2005)** found that sour orange seemed to be the most susceptible citrus plant to CLM among the tested ones; while, mandarin represented the least preferred host plant to it. **Wilson (1991), Knapp *et al.* (1995) and Bermudez *et al.* (2004)** found higher infestation levels on orange and grapefruit than on other citrus species. According to **Price (1992)**, resource use by herbivore insect populations is a result of complex interactions between detailed requirements of individual herbivores and biotic and abiotic variables affecting resource availability.

Table 7. Effect of the tested compounds against citrus leafminer larvae in navel orange orchard at Inshas District, Sharkia Governorate during spring season of 2017

Treatment	No. before treatment	Mean no. of CLM larvae after treatment (in days)							
		1	3	5	7	9	11	14	Avg.
Lambda	27.0±2.0	0.0±0.0	5.3±1.5	6.0±2.0	10.7±1.5	11.0±2.0	19.0±1.0	20.7±1.5	10.4
Abamectin	19.7±1.5	1.0±0.0	4.7±1.5	7.3±1.5	11.3±1.5	13.3±1.5	15.0±1.0	18.3±1.5	10.1
Acetamipride	20.7±2.5	4.7±1.5	5.7±1.5	9.3±1.5	13.0±2.0	16.0±2.0	17.3±1.5	19.0±1.0	12.1
KZ oil	23.3±2.1	5.3±1.5	4.0±2.0	1.0±0.0	0.0±0.0	0.0±0.0	11.7±1.5	20.7±2.1	6.1
Albolium	28.0±2.0	6.7±1.5	6.3±1.5	0.0±0.0	4.0±1.0	19.0±2.0	20.3±1.5	23.0±1.0	11.3
Super misrona	25.0±2.0	5.7±1.5	6.0±2.0	3.7±1.5	2.0±1.0	0.0±0.0	11.3±1.5	22.3±1.5	7.3
Diver	22.7±2.5	3.0±2.0	6.0±2.0	4.3±1.5	0.0±0.0	15.3±1.5	14.7±1.5	17.3±1.5	8.7
Control	23.7±2.5	22.0±1.0	26.3±2.5	29.3±1.5	24.7±1.5	28.0±2.0	20.3±2.5	22.7±1.5	24.8
LSD $_{(P=5\%)}$	3.76	2.31	3.21	2.42	2.21	2.78	2.73	2.60	2.18
F	5.25	78.64	47.90	132.5	132.0	102.4	15.65	5.97	57.08
P	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000

Table 8. Reduction percentages of citrus leafminer larvae caused by the tested compounds in navel orange orchard at Inshas District, Sharkia Governorate during spring season of 2017

Treatment	Initial effect	Reduction (%) of CLM larvae after treatment (in days)						Mean residual effect (%)	General effect (%)
		3	5	7	9	11	14		
Lambda	100	82.3	82.0	62.0	65.5	17.8	20.0	54.9	77.5
Abamectin	94.5	78.5	70.0	45.0	42.9	11.1	3.0	41.8	68.1
Acetamipride	75.5	75.2	63.7	39.7	34.6	2.4	4.2	36.6	56.1
KZ oil	75.5	84.5	96.5	100	100	41.4	7.2	71.6	73.6
Albolium	74.2	79.7	100	86.3	42.6	15.4	14.2	56.4	65.3
Super misrona	75.4	78.4	88.0	92.3	100	47.2	6.9	68.8	72.1
Diver	85.8	76.2	84.7	100	42.9	24.4	20.4	58.1	72.0

So, **Goane *et al.* (2008)** mentioned that some degree of CLM preference for lemon trees could be explained by their greater temporal stability as a resource for it. On the another hand, the same authors found that lemon, orange, and grapefruit seem to represent intrinsically similar resources for CLM populations in northwest Argentina, a trend that was accompanied by a lack of consistent oviposition preferences in foraging females. The same authors added that oviposition behavior and performance of CLM could be determined by ecological conditions or resource availability rather than by physiological adaptation of larvae to each citrus species. Moreover, the inconsistent preferences shown by CLM females suggest an evolutionarily labile host order of preference (**Carrie´re, 1998; Smyth *et al.*, 2003**). According to **Gotthard *et al.* (2004)**, there was an evidence of geographic variations in oviposition preferences of phytophagous insects. Also, **Messina (2004)** added that lability of host preference has been shown to vary among populations, which precludes generalization at the species level. Finally, different preference performance patterns might be detected if other citrus species were considered, because host ranking might vary depending on the options available (**Martin *et al.*, 2005**). These findings could explain the variations between the present results and others.

According to the chemical analysis of leaves, the preference of CLM to navel orange may be attributed to its highly content of carbohydrates, nitrogen, phosphorus, potassium, iron, protein and ascorbic acid, in addition to its lowest content of glucose. On the contrary, the lowest preference of CLM to bitter orange may be attributed to the lowest content of nitrogen, phosphorus, potassium, protein and humidity, in addition to its highest content of zinc, beta carotene and dry weight. **Elkady (2005)** studied the effect of volatile oils leaf content on CLM host preference and found that navel orange had high percentages of linalool and β-pinene; while, mandarin had a low percentage of eugenol. **Steinbauer *et al.* (1998) and Kursar *et al.* (2006)** mentioned that the availability or predictability of suitable age class foliage can be even more important than physical or chemical differences among host species in determining preferences of phytophagous insects. Citrus species show different flushing patterns throughout the year; thus, interspecific differences in temporal availability of young leaves could greatly affect host use by CLM (**Jacas *et al.*, 1997 ; Goane *et al.*, 2008**).

The activity of citrus leafminer was higher in west direction in comparison with the other cardinal directions and center of its host trees; while, center had the lowest activity of CLM. This experiment was done during spring season; so, female of CLM may search for a moderate shaded side of its host tree which will be suitable for its offspring during this season. Also, **Bakr *et al.* (2009) and El-Metwally *et al.* (2011)** found that the white mango scale insect, *Aulacaspis tubercularis* Newstead preferred west direction of its host tree especially during spring season.

With respect to the control of CLM, the obtained results showed that KZ oil is the most effective treatment in controlling CLM infesting navel orange trees. Lambda, super misrona, diver, albolium and abamectin exhibited moderate ranks in controlling CLM; while, acetamipride was the lowest effective treatment against CLM in comparison with the other tested treatments under field conditions. These results are in agreement with those obtained by **Beattie *et al.* (1995)** (in Australia), **Rae *et al.* (1996)** (in China), **Besheli (2010), Qureshi *et al.* (2011)** (in Florida), **Damavandian and Moosavi (2014)** (in Iran), and **Ghanim and Elgohary (2015)** (in Egypt); they mentioned that mineral oils exhibited effective roles in controlling CLM in citrus orchards. The effectiveness of mineral oils may be related to their adjuvant ingredient which might reduce the infestation by acting as an oviposition deterrent in the field (**Besheli, 2010**). According to **Mohamed and Satti (2015)**, lambda was of the effective treatment in controlling CLM on citrus trees in Sudan. Abamectin was of the lowest effective treatments against CLM, this may be attributed to its rapidly break down (< 1 day) when exposed to sunlight or when present as a thin film (**Clark *et al.*, 1995**). While, **Rae *et al.* (1996)** and **Damavandian and Moosavi (2014)** mentioned that the mixture of mineral oil plus abamectin exhibited a high effect against CLM under field conditions with reduction percentages ranged between 85 and 100%. The higher effect of this mixture was explained by **Lasota and Dybas (1991)**; who demonstrated that reservoirs of the chemical can remain within the mesophyll layer of leaves, particularly when this chemical is applied with oil. Thus, abamectin becomes much more accessible to pests such as the leafminer, than to their predators or parasites. **Raga *et al.* (2001)** added that abamectin and lufenuron, along with petroleum oil, resulted in a significant increase in CLM larval activity. However, the efficacy of petroleum spray oils used as oviposition deterrents to control CLM is related to time of spraying, the dose of oil and the persistence of oil molecules on sprayed surfaces (**Mertz and Yao, 1993**). Therefore, petroleum oil alone or as an adjuvant for a pesticide - less harmful on the environment is recommended for IPM programs (**Khyami and Ateyyat, 2002**).

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التفضيــل العــوائلي، التـــوزيـــع المكاني والمكافحـــة الكيميائية لصانعـة أنفـــاق أوراق المــوالــح

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تُعد حشرة صانعة أنفاق أوراق الموالح من أهم آفات مشاتل الموالح والأشجار الحديثة منها، ويهدف هذا البحث إلى دراسة التفضيل العوائلي لهذه الآفة وتوزيعها المكاني داخل بيئة شجرة عائلها بالإضافة إلى مكافحتها كيميائياً في مزارع الموالح بمنطقة إنشاص – محافظة الشرقية، وقد أوضحت النتائج أنّ صانعة أنفاق أوراق الموالح تفضل بدرجة معنوية إصابة كل من البرتقال أبو سرة والليمون الأضاليا عن البرتقال الصيفي، اليوسفي، البرتقال البلدي والنارنج، وربما يرجع تفضيل هذه الآفة للبرتقال أبو سرة إلى ارتفاع محتوى أوراقه من بعض المكونات مثل الكربوهيدرات، النيتروجين، الفوسفور، البوتاسيوم، الحديد، البروتين وحمض الأسكوربكَ مقارنة بالعوائل الأخرى محل الدراسة، وعلى النقيض فإن قلة تفضيل الآفة للنارنج ربما يرجع إلى انخفاض محتوى أوراقه من النيتروجين، الفوسفور، البوتاسيوم، البروتين والرطوبة، ومن ناحية أخرى فقد أوضحت النتائج أنه خلال فترة الربيع تنتشر هذه الآفة في الجهة الغربية من شجرة العائل أكثر من الاتجاهات الأخرى أو المنتصف، كما أوضحت نتائج المكافحة تحت الظروف الحقلية أنّ الزيت المعدني كزد هو الأكثر تأثيراً في خفض تعداد صانعة أنفاق أوراق الموالح على أشجار البرتقال أبو سرة؛ بينما كل من مبيد لامبادا، زيت سوبر مصرونا، زيت دايفر، زيت البوليوم ومبيد أباميكتين ذوي تأثيرات متوسطة نسبياً في مكافحة هذه الآفة؛ أما مبيد أسيتاميبريد فقد كان هو الأقل كفاءةً.

المحكمون :

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