EFFECTIVENESS OF FOUR INSECTICIDES TO CONTROL CITRUS LEAFMINER (*PHYLLOCNSTIS CITRELLA* STAINTON) (LEPIDOPTERA: GRACILLARIDAE) ON ORANGE TREES AT RIVER NILE STATE, SUDAN

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ABSTRACT

The efficacies of four insecticides with two different formulations liquid and solid viz; two as foliar sprays, Match 050 EC (lufenuron) and Icaros 1.8% EC (abamectin) as well as soil drench of Actara 25% WG (thiamethoxam) and Furadan 10% G (carbofuran) to control citrus leafminer (CLM) in orange orchard located in River Nile State during winter seasons 2015and 2016. The experiment was assigned in a randomized complete block design (RCBD) with three replications. At each year two foliar and soil drench insecticidal were applied one time in late January. CLM larval counts were recorded at 3, 7, 14 and 21 days after treatment (DAT). Results showed that regardless the agricultural season and the time of all tested insecticidal application nearly almost suppressed in the number of CLM larvae compared to the untreated-control. At the 21st day after treatment (DAT), the insecticidal activities of all chemicals were declined. However, the two formulations, Actara and Furadan exhibited the highest residual activity more than three weeks compared to the tow foliar sprays by Icaros 1.8% EC or Match 050 EC. Thus, Actara 25% WG and Furadan10% G showed the higher soil drench insecticidal activity and persistence against CLM infestation on orange trees.

Keywords: Keywords: **Orange, Citrus leafminer, Chemical control, *Phyllocnistis citrella* and Sudan**

تقييم بعض المبيدات الحشرية المختلفة لمكافحة صانعة أنفاق أوراق الموالح على البرتقال فى ولاية نهر النيل، السودان.

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المستخاص

تم تقييم فاعلية أربعة من المبيدات الحشرية إثنان عن طريق الرش ليفرون (ماتش 050 EC) وأبامكتين (أكاروس 1.8% EC) وكذلك مبيدى سيماسكسام (أكتارا 25 WG) وكاربوفيوران (فيوردان 10% G) عن طريق التجريع لمكافحة يرقات صانعة أنفاق أوراق الموالح في بستان البرتقال الذى يقع في ولاية نهرالنيل خلال عامى 2015 و 2016. صممت التجربة بتصميم القطاعات العشوائية الكاملة كل معاملة تحتوى على ثلاث مكررات وكل مكررة تحتوى على شجرتين وذلك فى كل عام من عامى الدراسة . عوملت هذه الأشجار رشا وتجريعاً مرة واحدة فى العامين من الدراسة فى أواخر يناير، وتم تسجيل أعداد اليرقات قبل الرش وبعد 7، 3 ، 14 و21 يوم من المعاملة .أظهرت النتائج وبغض النظر عن عام الدراسة ووقت تطبيق المبيدات – أن أعلى معدلات المكافحة ظهرت بعد سبعة أيام من المعاملة. لوحظ أن هناك انخفاض فى معدلات المكافحة بدءا من اليوم الحادى والعشرون بعد المعاملة. أظهر المبيدان أكتارا وفيورادان فاعلية لوقت أطول بعد المعاملة. بينما أوضحت النتائج أن تتطبيق المبيدات عن طريق التجريع زاد من فاعليتها وبقائها لفترة أطول. وعلى ضوء النتائج السابقة فإنه ينصح باستخدام مبيدى أكتارا وفيورادان عن طريق التجريع بالإضافة الى مبيد الماتش وأكاروس للحصول على أعلى نسبة مكافحة لحشرة صانعة أنفاق أوراق الموالح على أشجار البرتقال.

كلمات مفتاحية: برتقال، صانعة أوراق الموالح، مكلفحة كيميائية ، *Phyllocnistis citrella* والسودان

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INTRODUCTION

Sudan offers great potentialities for citrus production due to the wide variability in climate, soil types and geographical conditions. In recent trend in agricultural sector reveals genuine interest to expand the areas of citrus crops in near future. The important citrus species grown in different parts of the country may include, baladi (local) lime (*Citrus aurantifolia* L.) grapefruit (*C. paradise* Macf) sweet orange (*C. sinesis* L. Osb.) lemon (*C. limon* L. Burm) and mandarin (*C. reticulate* Blanco). The bulk of production is consumed locally and little amount generally exported to some Arabian and European countries (6). Many citrus pests and diseases have been reported in different growing areas of the country. However, among the bioagressor which attack oranges trees, we noted the Mediterranean fruit fly (*Ceratitis capitata*) California red scale (*Aonidiella aurantti*) citrus mealy bug (*Planococcus citri*) lemon butter fly (*Papilio demodocus*) and citrus leafminer (*Phyllocnistis citrella*) (2,9). The last bioagressor belongs, family of Lepidoptera: Gracillariidae and is one of the serious insect pest of nursery as well as young trees of citrus (7). The activity of the pest is normally observed through the year due to its overlapping generation, however new flushes leaves are more exposed. Their larvae feed on the epidermis of the tender leaves making serpentine mines due to leaves became distorted and crumpled. This adversely affects the photosynthesis activity which results in reduced vigour and growth of the plant. It was estimated that nearly 45% of new leaf area was lost due to citrus leafminer infestation (3). Moreover, it has been also associated with the transmission of citrus canker disease caused by *Xanthomonas axonopodis* pv. citri (5 ,1). The chemical control is considered as the main method adopted to control citrus leafminer in all continents. Many chemical families of insecticides like (pyrethroids, carbamates and organophosphates) are generally used against *P. citrella* in different countries (15). Nevertheless, chemical control of citrus leafminers in Florida was reported to increase yield in 3 to 5 years-old grapefruit or orange trees by 13.1 to 16.9% respectively (12). Whereas insecticides applied to the ground for young trees or to the soil of potted citrus provides the longest period of control (1-3 months) (4). The objective of this study was to evaluate the efficacy of some insecticides against the citrus leafminer infesting orange trees in the River Nile State, Sudan.

MATERIALS AND METHODS

Field experiments were conducted at River Nile State, Sudan during winter seasons 2015 and 2016 to evaluate various insecticides against *P. citrella* on orange trees of more than five years old. Treatments were assigned in a randomized complete block design (RCBD) with three replications. The treatments included two foliar sprays, Match 050 EC (lufenuron) each at 4.6 and 5.8 ml/liter of and Icaros 1.8% EC (abamectin) each at 1.8 and 2.2 ml/liter of water as well as soil drench of Actara 25% WG (thiamethoxam) at 1.2 g/tree and 1.5 g/tree and Furadan 10% G (carbofuran) at 20 g/tree and 25 g/tree and the untreated-control. Two trees as the plot were assigned at random to each of the four products treatments. The whole trees which selected as foliar treatment were sprayed to run-off using knapsack sprayer at one-liter water spray per tree. In both seasons one spray and soil drench were applied on 28, January 2015 and 3rd of February 2016. A pre-spray count preceded each treatment by 24 h and the post-spray counts ones were carried after 3, 7, 14 and 21 days. Observations included the number of larvae per 10 flush leaves and the number of total and infested flush leaves. Mines in initial stages, that did not cause significant damage or curling of leaves were not considered and left to the subsequent counts. The percent infestation was calculated by number of infested flush leaves divided by the total number of flush leaves multiplied by one hundred. Percentage of infestation by using the following equation:

$$\text{Percentage of infestation} = \frac{\text{the number of leaves infested}}{\text{Total no. of leaves sampled}} \times 100$$

The percentage of infested flush leaves and the numbers of larvae were recorded. The data collected were analyzed after transformed to $\sqrt{x+0.5}$. MSTAT-C software program was used for analysis of Variance (ANOVA) and

Duncan's Multiple Range Test (DMRT) was used for means separation.

RESULTS AND DISCUSSION

The efficacies of four insecticides viz; two as foliar sprays, Match 050 EC (lufenuron) and Icaros 1.8% EC (abamectin) as well as soil drench of Actara 25 WG (thiamethoxam) and Furadan 10% G (carbofuran) against citrus leafminer (CLM) in orange trees, located at River Nile State during 2015 and 2016 were presented in (Table 1, 2, 3 and 4). The results showed that in the first three weeks post counts all insecticides were significantly effective in suppressing larval population and consequently reduction of infestation in comparison to the untreated-control. The observation recorded on the 4th week and 5th week after treatment revealed that thiamethoxam treatment had recorded the lowest pest population followed by carbofuran, abamectin and lufenuron (Table 1).

Table 1. Mean number of citrus leafminer larvae per ten infested flush leaves at different levels of some insecticides treatments on orange trees at River Nile State, Sudan season 2015.

Treatments	Pre-spray count	Post-spray counts				General performance
		3 DAS 31/01/015	7 DAS 7/02/015	14 DAS 14/02/015	21 DAS 21/02/2015	
Match 050 EC at 4.6 ml/liter	(6.0)	0.9 (0.3)	1.2 (1.0)	1.5 (2.0)	3.7 (13.5) bc	1.8 ab
Match 050 EC at 5.8 ml/l	(6.3)	0.9 (0.3)	1.1 (0.8)	1.3 (1.3)	3.4 (11.0) abc	1.7 ab
Icaros 1.8 EC at 1.8 ml/l	(8.3)	0.9 (0.3)	2.0 (3.5)	1.7 (3.0)	3.3 (10.3) ab	2.0 ab
Icaros 1.8 EC at 2.2 ml/l	(7.3)	0.7 (0.0)	1.2 (1.0)	1.7 (3.0)	2.0 (3.6) ab	1.4 ab
Actara 25 WG at 1.2 g/tree	(7.7)	0.9 (0.3)	0.7 (0.0)	1.7 (3.0)	3.8 (14.5) bc	1.8 ab
Actara 25 WG at 1.5 g/tree	(8.7)	0.7 (0.0)	0.7 (0.0)	1.5 (2.0)	3.0 (8.5) ab	1.5 a
Furadan 10% G at 20 g/tree	(7.5)	0.9 (0.3)	1.6 (2.3)	2.1 (4.5)	4.8 (23.2) cd	2.4 bc
Furadan 10% G at 25 g/tree	(8.0)	1.2 (1.0)	1.5 (2.0)	1.3 (1.3)	3.8 (15.0) a	2.0 a
Untreated-control	(8.3)	1.4 (1.5)	2.0 (3.5)	2.7 (7.0)	5.2 (27.5) d	2.8 c
SE±	0.6318 n.s	0.1714 n.s	0.3089 n.s	0.4388 n.s	0.4328**	0.2086**
C.V%	13.5	29.7	40.6	36.7	20.4	22.0

Data transformed according to the √x+0.5, Actual figures in parenthesis; DAS = Days after spray; n.s = not significant;

- = significant at 1% level. Means followed by the same letter (s) with the same column are not significantly different at 1% level of probability according to Duncan Multiple Range Test (MRT).**

Moreover, after the 4th week, thiamethoxam showed less percentage of infestation followed by carbofuran, lufenuron and abamectin. Amongst different insecticides tested against citrus leafminer in orchard, soil drench was superior in performance followed by the two foliar sprays (lufenuron and abamectin) (Table 2). The data showed a significant reduction in all insecticidal treated plots and the untreated plots in CLM larval population up to the forth week. Thiamethoxam proved to be the best active ingredient in reducing the population of citrus leafminer, following by carbofuran, abamectin and lufenuron, respectively (Table 3).

Table 2. Percentage of infested flush leaves with the citrus leafminer at different levels of some insecticides treatments on orange trees at River Nile State Sudan season 2015

Treatments	Pre-spray count	Post-spray counts				General performance
		3 DAS 31/01/2015	7 DAS 7/02/2015	14 DAS 14/02/2015	21 DAS 21/02/2015	
Match 050 EC at 4.6 ml/liter	(9.9)	2.3 (4.8) abc	3.0 (8.5) a	4.1 (16.9) cdef	4.7 (22.3) d	3.5 b
Match 050 EC at 5.8 ml/l	(8.2)	2.1 (4.0) ab	2.6 (6.3) a	3.2 (9.8) ab	4.3 (17.8) cd	3.3 b
Icaros 1.8 EC at 1.8 ml/l	(7.2)	2.4 (5.2) abc	2.6 (6.3) a	4.2 (17.4) cdef	4.1 (16.9) bcd	3.3 b
Icaros 1.8 EC at 2.2 ml/l	(7.9)	2.3 (5.0) abc	2.4 (6.0) a	3.3 (10.5) ab	4.0 (15.4) bc	3.0 a
Actara 25 WG at 1.2 g/tree	(9.3)	2.6 (6.5) bc	2.6 (6.3) a	3.6 (12.4) ab	3.8 (14.1) ab	3.2 a
Actara 25 WG at 1.5 g/tree	(8.5)	2.0 (3.5) a	2.4 (6.0) a	2.6 (6.3) a	3.6 (12.6) ab	2.7 a
Furadan 10% G at 20 g/tree	(9.8)	2.7 (7.0) cd	3.1 (9.2) a	3.8 (14.3) bcd	3.8 (13.9) ab	3.4 ab
Furadan 10% G at 25 g/tree	(11.1)	2.5 (5.6) abc	2.9 (8.2) a	2.9 (7.5) a	3.5 (11.8) a	3.0 a
Untreated-control	(8.4)	3.2 (9.9) d	4.0 (15.6) b	4.9 (24.0) f	5.5 (29.7) d	4.4 c
SE±	1.034 n.s	0.1732**	0.4778*	0.2352**	0.2280**	0.1745**
C.V%	18.3	21.2	13.7	10.4	10.3	10.6

Data transformed according to the √x+0.5, Actual figures in parenthesis; DAS = Days after spray; n.s = not significant; ** = significant at 1% level. Means followed by the same letter (s) with the same column are not significantly different at 1% level of probability according to Duncan Multiple Range Test (MRT).

Table 3. Mean number of citrus leafminer larvae per ten infested flush leaves leaves at different levels of some insecticides treatments on orange trees at, River Nile State, Sudan season 2016

Treatments	Pre-spray count	Post-spray counts				General performance
		3 DAS 06/02/2016	7 DAS 13/02/2016	14 DAS 20/02/2016	21 DAS 27/02/2016	
Match 050 EC at 4.6 ml/liter	(14.9)	1.5 (2.0) a	2.2 (4.3) ab	3.8 (14.1) cd	4.3 (17.8) b	3.0 ab
Match 050 EC at 5.8 ml/l	(16.6)	1.3 (1.3) a	1.7 (2.3) a	2.8 (7.3) ab	3.6 (12.6) a	2.4 a
Icaros 1.8 EC at 1.8 ml/l	(19.4)	1.4 (1.7) a	1.8 (3.0) a	3.3 (10.4) bc	3.9 (14.7) ab	2.6 ab
Icaros 1.8 EC at 2.2 ml/l	(19.0)	1.3 (1.3) a	1.8 (3.0) a	2.5 (5.9) a	3.8 (13.7) ab	2.4 a
Actara 25 WG at 1.2 g/tree	(22.1)	1.1 (0.9) a	2.6 (6.1) b	3.0 (8.7) ab	4.2 (16.8) b	2.7 ab
Actara 25 WG at 1.5 g/tree	(16.2)	1.1 (0.8) a	1.7 (2.3) a	2.5 (6.1) a	3.5 (11.9) a	2.2 a
Furadan 10% G at 20 g/tree	(18.9)	1.4 (1.7) a	2.0 (3.6) a	3.2 (10.1) abc	4.0 (16.0) ab	2.7 ab
Furadan 10% G at 25 g/tree	(16.1)	1.3 (1.3) a	1.6 (2.2) a	2.5 (6.5) a	3.9 (15.0) ab	2.3 a
Untreated-control	(17.2)	2.3 (5.1) b	2.6 (6.4) b	4.1 (16.6) d	4.8 (22.7) c	3.5 c
SE±	1.323 n.s	0.1889*	0.1703*	0.2236**	0.1581**	0.1387**
C.V%	12.9	23.2	14.7	12.5	6.9	10.6

Data transformed according to the √x+0.5, Actual figures in parenthesis; DAS = Days after spray; n.s = not significant; * and ** significant at 5% and 1% level. Means followed by the same letter (s) with the same column are not significantly different at 1% level of probability according to Duncan Multiple Range Test (MRT).

Soil application with thiamethoxam and carbofuran proved the most effective against the citrus leafminer and gave prolonged control effects for at least one month, followed by the sprays; abamectin and lufenuron. Moreover, the two soils applied chemicals, thiamethoxam and carbofuran, also obtained the best results in combating leafminers and significantly reduced damage. In the general performance, the percent infestation of *P. citrella* indicated that all the treated plots were significantly superior over untreated-control. The lowest percent infested flush leaves 3.1% was recorded by thiamethoxam followed by 3.2% per flush leaves by carbofuran. Whereas the two foliar sprays (lufenuron and abamectin) which recorded 3.4% and 3.6% per flush leaves, respectively (Table 4).

Table 4. Percentage of infested flush leaves with the citrus leafminer at different levels of some insecticides treatments on orange trees at River Nile State Sudan, season 2016

Treatments	Pre-spray count	Post-spray counts				General performance
		3 DAS 06/02/2016	7 DAS 13/02/2016	14 DAS 20/02/2016	21 DAS 27/02/2016	
Match 050 EC at 4.6 ml/liter	27.0	2.7 (6.9) bc	4.0 (15.8) bc	4.0 (15.7) b	5.0 (24.8) b	3.9 d
Match 050 EC at 5.8 ml/l	27.8	2.0 (3.5) a	3.7 (13.3) b	3.7 (13.5) ab	4.3 (18.1) ab	3.4 cd
Icaros 1.8 EC at 1.8 ml/l	29.8	2.7 (6.6) bc	4.3 (17.8) bc	4.3 (18.0) b	4.6 (21.0) ab	4.0 d
Icaros 1.8 EC at 2.2 ml/l	26.9	1.9 (3.3) a	3.9 (14.5) bc	3.9 (14.7) b	4.2 (17.5) a	3.5 cd
Actara 25 WG at 1.2 g/tree	28.6	2.6 (6.4) bc	3.1 (8.9) a	3.7 (13.4) b	4.1 (16.1) a	3.4 cd
Actara 25 WG at 1.5 g/tree	32.5	2.3 (4.7) ab	3.1 (9.3) a	3.1 (9.6) a	4.1 (16.6) a	3.1 a
Furadan 10% G at 20 g/tree	34.7	2.6 (6.1) bc	4.2 (17.3) bc	4.1 (16.6) b	4.5 (20.5) ab	3.9 d
Furadan 10% G at 25 g/tree	29.6	2.3 (4.6) ab	2.9 (8.1) a	3.6 (12.8) ab	4.1 (16.8) a	3.2 ab
Untreated-control	29.5	3.0 (8.6) c	4.4 (19.1) c	5.2 (26.1) c	5.0 (24.8) b	4.4 e
SE±	1.796 n.s	0.1683*	0.1742**	0.2113**	0.2229*	0.1405**
C.V%	9.8	12.0	7.9	9.4	8.7	7.7

Data transformed according to the √x+0.5, Actual figures in parenthesis; DAS = Days after spray; n.s = not significant; * and ** = significant at 5% and 1% level. Means followed by the same letter (s) with the same column are not significantly different at 1% level of probability according to Duncan Multiple Range Test (MRT).

The results for the both years considered that all the insecticide treatments were found to be effective against citrus leafminer in orange trees. The treatment with thiametoxam and carbofuran were found most effective with the lowest percent infestation overall the treatments at 14 and 21 days after spray. These findings highlighted that soil applied with such neonicotinoid insecticides can prevent damage by citrus leafminers for more than one month, which was longer than that obtained by the abamectin and lufenuron spraying. Setamou et al. (10); Sharma et al., (11) and Stansly et al., (13) stated that drenches of imidacloprid and Actara can suppress the same pest on citrus seedlings and young trees for one to three months. In the present study the thiamethoxam was found to be effective is in agreement with Raga et al., (8) who reported that the thiamethoxam effectively controls citrus

leafminer. The effectiveness of thiamethoxam against citrus leafminer in this investigations are similar with the finding of Shinde et al (14) who found a superior effective among the treatments. Effectiveness of abamectin against citrus leafminer, was recorded in the present investigation is in agreement with Patil (7) who also found that the Abamectin was superior over other treatments like spinosad, novaluron, acephate and diafenthiuron and it was helpful in reducing percent infestation of leaves caused by citrus leafminer in acid lime. The soil application technique appeared to be advantageous over foliar sprays because there is a reduction in the frequency of application in citrus nurseries and orchards resulting in minimum exposure of such broad spectrum insecticides to beneficial insects. Also, the residues of these insecticides seemed to be easily degraded as they need to be reapplied every 14 to 21 days to ensure good control of leafminers for 15 days. Thus, by using the two chemicals former soil applied insecticides such as Actara and Furadan which showed maximum larval mortality with the highest persistence not only protect the natural enemies but also the environment by reducing the number of sprays. Also, drench application is save and cheaper in the application as they will be applied by farmers. As well as, it is safe for use of consumers as fruits will be free from insecticides residues**.**

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