DOI: 10.21608/alexja.2024.265470.1061

Potentiation of Spirotetramat and Sulfoxaflor Activity on *Milviscutulus mangiferae* (Green) by Mixing with Nimbecidine Bio-insecticide

Mohamed Rezk[1], Ahmed S. Abdel-Aty[2]*

[1]*Scale insect and Mealy bugs Department, Plant Protection Research Institute, Sabahia Plant Protection Station, Agriculture Research Center, Alexandria, Egypt.*

[2]*Department of Pesticide Chemistry and Technology, Faculty of Agriculture, Alexandria University, 21545-El-Shatby, Alexandria, Egypt.*

*Corresponding Author E-mail: sabry2000@yahoo.com; ahmed.abdelatty@alexu.edu.eg

ARTICLE INFO

Article History

Received: 25/1/2014

Revised:14/2/2024

Accepted: 14/2/2024

Key words: *Milviscutulus mangiferae*; Spirotetramat (Movento); Sulfoxaflor (Isoclast); KZ Oil; Nimbecidine®

ABSTRACT

Six treatments of some insecticides with different modes of action were tested against the mango shield scale (MSS), *Milviscutulus mangiferae* (Green) different stages on mango host plant trees. This study aimed to differentiate among the used insecticides (Spirotetramat (Movento), 10% SC; sulfoxaflor (Isoclast), 50% WG and mineral oil (KZ Oil®) 95% EC) regarding their reduction of each *M. mangiferae* stage as well as its total population. Nimbecidine 0.03% (Azadirachtin) bio-insecticide was mixed with the Spirotetramat (Movento®) and sulfoxaflor (Isoclast®) at half application rate of each. All the treated insect stage populations were differently affected in a function of the treated stage, the tested compound, and the time after treatment (exposure time) with continuous high activity even after 8 weeks of treatment. The differences in the effect are due to their different modes of action. Both the 1st and the 2nd nymph instars were less affected than the other treated stages (adult and crawler) with all the tested insecticides. The obtained reduction % appeared in a non-systematic arrangement with the time of exposure. The mineral oil (Kz oil®) appeared the most effective, followed by the mixture of Nimbecidine® 0.03% azadirachtin at 250 ml/100 L and Sulfoxaflor (Isoclast®) 50% WG at 62.5 gm/ 200 L; Sulfoxaflor (Isoclast®) 50% WG at 125 gm/ 200 L; the mixture of Nimbecidine® 0.03% at 250 ml/ 100 L and Spirotetramat (Movento®) 10% SC at 20 ml/ 200 L; Spirotetramat (Movento®) 10% SC at 40 ml/ 200 L and Nimbecidine® 0.03% (azadirachtin) at 500 ml/ 100 L. Mixing the bio-insecticide Nimbecidine® 0.03% azadirachtin with the synthetic insecticides at half the application rate of each enhanced the reduction by decreasing their harmful effects on the environment and non-target biota.

INTRODUCTION

Mango, *Mangifera indica* L. (Anacardiaceae) is a popular fruit in Egypt with high economic importance worldwide for its flavor and taste (Karar *et al*., 2015). The mango shield scale, *Milviscutulus mangiferae* (Green) (Hemiptera: Coccidae) is a polyphagous insect damaging several plant families. It is a very serious problematic insect of mango (Malumphy, 2018) destroying the fruit crop (Abd-Rabou and Evans, 2018; Attia *et al.*, 2018 and El-Baradey *et al.*, 2020) through sucking the plant juice. This insect also injures all of the plant parts including shoots, twigs, leaves, branches, and even fruits with its toxic saliva Several features as chlorosis, deformations, defoliation, drying up of young twigs, followed by dieback and poor blossoming causing the death of twig and branches (Soliman *et al*., 2007; Grimshaw and Donaldson, 2007; Hassan *et al.*, 2012 and Bakry *et al.*, 2013). Large honeydew amount that is normally excreted from this insect attracts ants on leaves and encourages the growth of sooty mold fungus, which exhibits a dirty black appearance reducing photosynthesis and respiration while lowering the fruit quality and leading to considerable economic loss (Atalla *et al*., 2007 and Nabil, 2013). The information on population density and fluctuations of *M. mangiferae* during the year helps mango producers in its management. Mohamed (2020) indicated that *M. mangiferae* is active all the year with three peaks of activity on mango trees in January, July and November. Parthenogenetic reproduction, walking all stages over the host to a suitable place to settle and feed (Kasuya, 2000) and morphological adaptation for passive dispersal by the wind of *M. mangiferae* help its widespread and danger.

Several synthetic insecticides are used for controlling the sucking insects.

Imidacloprid, clothianidin, and sulfoxaflor exhibited repellency, feeding reduction and body weight loss in *S. graminum* and *C. septempunctata* adults (Bilal *et al.* (2020). Due to the expected environmental harmful effect of the synthetic insecticides, bio-insecticides are encouraged to be used (Rezk and Abel-Aty, 2023). Seed extracts of the neem tree, *Azadirachta indica* A Juss, have been used for centuries as a botanical insecticide and approved for use in organic agriculture (Schmutterer, 1995)

So, in this study, some insecticides with different modes of action were tested against the mango shield scale (MSS) insect in different stages on mango host plant trees in December 2021 and December 2022. This study aimed to differentiate among the used insecticides (spirotetramat (movento®), 10% SC; sulfoxaflor (isoclast®), 50% WG; Nimbecidine® 0.03% (Azadirachtin) as a botanical insecticide and a mineral oil (Kz oil®) (95% EC) for their reduction effect in population against each *M. mangiferae* stage as well as its total population to stand on the most preferable insecticide among them to be used for controlling the treated insect. A mixture of the used botanical insecticide (Nimbecidine® 0.03% (Azadirachtin) with both the two synthetic insecticides individually at the half rate of each component in the mixture to evaluate the effect of this mixing process on the reduction effect as well as to safe the environment.

MATERIAL AND METHODS

1- Treated Insect

The mango shield scale, *M. mangiferae* (Green) is the most spreader and the most effective in the treatment region. The treated insect was identified through photographing with a stereomicroscope at 40X magnification of its all stages (eggs, crawlers, the adult insect, the first instar, and the second star) (Rezk and Abdel-Aty, 2023) as shown in Figure 1.

2- Used insecticides

Six treatments of four commercial insecticides with different chemical groups and their mixtures were tested for their reducing effects against the different stages of the mango shield scale, *M. mangiferae* (Green). These insecticides were applied at their recommended rates. The origin, common and trade names, formulation, application rate, chemical class and chemical structure of the tested insecticides are listed in Table (1).

3- *In Situ* Treatment procedure

All insect stages were treated in the fruity mango trees in Rashid City, Behira Governorate, Egypt. The treatment of mango shield scale insect stages was done using the foliar application on the host plant trees, which were not chemically treated two years before this study. Randomized complete block design (RCBD) was used. Four trees were taken for each replicate and four replicates were considered as a treatment. The host plant trees were sprayed once with the tested insecticides at their application rates, while the mixtures were used at half rates of each component (Table 1) using 20-liter knapsack sprayer. Fifty leaves of each replicate were randomly taken directly before spraying (pre-spraying) for counting the treated insect stages and the infestation limit was determined. This step was repeated at 2, 4, 6, and 8 weeks after treatment in both treatment and control. The count and discrimination of each stage alive number were carried out using the stereomicroscope. Counting was repeated four times in each replicate and its mean number was calculated. The four mean numbers of the four replicates were averaged for each treatment. Control was concurrently conducted. The reduction percentage in each studied stage and the total population was calculated according to (Henderson and Tilton, 1955) formula.

Reduction % = $100 [1- (T_2 / T_1 * C_1 / C_2)]$

T_2 Population in Treatment after spray

T_1 Population in Treatment before spray

C_1 Population in control before spray

C_2 Population in control after spray

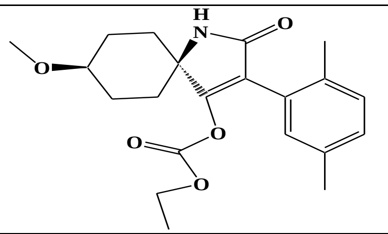
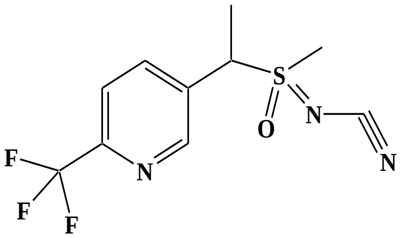
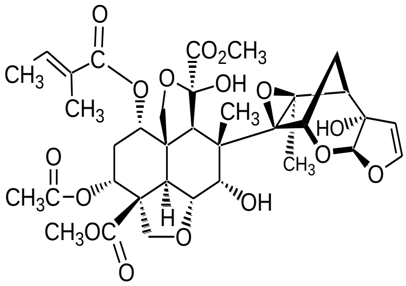
4- Statistical Analysis

The collected data underwent analysis of variance in accordance with the methodology outlined by Gomez and Gomez (1984). Statistical analysis was conducted utilizing the analysis of variance technique through the Costat computer software package (CoStat, Ver. 6.311., 2005). The least significant difference (LSD at 0.05) was employed for comparing the treatment means.

***M. mangiferae* on mango leaves** **Eggs** **Crawler** **First instar** **Second instar**

Figure 1. A photo guide of *M. mangiferae* (Green) identification (Rezk and Abdel-Aty, 2023).

Table 1: The tested insecticides against *Milviscutulus mangiferae* (Green) insect stages

Common name (Trade name)	Chemical class	Basic manufacturer	Application rate	Chemical structure
Spirotetramat (Movento®) 10% SC	Tetramic acid derivative (Ketoenol)	Bayer Crop Science LP, Research Triangle Park, NC	40 ml/ 100 L	
Sulfoxaflor (Isoclast®) 50% WG	Sulfoximines	Dow AgroSciences, LLC, Indianapolis, IN	125 gm/ 100 L	
Nimbecidine® 0.03% (Azadirachtin)	Terpenoids	T. Stanes Company Limited Connecting Agri Needs	500 ml/ 100 L	
Nimbecidine® 0.03% (250 ml/ 100 L.) + Spirotetramat (Movento®) 10% SC (20 ml/ 200 L)				A tank mixture
Nimbecidine® 0.03% (250 ml/ 100 L) + Sulfoxaflor (Isoclast®) 50% WG (62.5 gm/ 200 L)				A tank mixture
(Kz oil®) 95% EC	Mineral oil	Kz Company for Pesticides and Chemical Industries, Egypt	1.5 L/ 100 L	

RESULTS AND DISCUSSION

The obtained results described the insecticidal effects of the synthetic insecticides (with different modes of action) as well as the used mineral oil. The treated insect stage populations were differently affected by a function of the treated stage, the tested compound, and the exposure time. After two weeks, the treated adult population was reduced for its census with a reduction % ranged from 88.42– 97.70% and 90.69 – 96.40% in seasons 2021 and 2022, respectively with the mineral oil treatment. This reduction effect was lowered in treatment with sulfoxaflor and spirotetramat as they caused reduction of the treated adult population equaled 81.30 – 92.04% and 79.06 – 90.70% reduction ranges, respectively in season 2021 and with 79.25 – 91.25% and 76.51 – 89.57% reduction ranges in season 2022, in the same array with no significance between the two insecticides in their mortal effects against the treated adult population.

Although the tested botanical insecticide (Nimbecidine 0.03% azadirachtin) appeared less effective in reducing the adult population with 52.01 – 67.73% and 49.68 – 65.37% reduction ranges in 2021 and 2022 seasons respectively, its tank mixture with spirotetramat at half application rate of each of them enhanced the reduction effect at all intervals after treatments specially after 8 weeks of treatment exhibiting 86.12 and 84.02 % reduction, comparing to 81.49 and 81.35% in case of application of spirotetramat alone in 2021 and 2022 seasons, respectively. The same trend of enhancement was achieved when mixed with sulfoxaflor. After 8 weeks of treatment, the mixture exhibited 89.29% and 86.82% reduction in adult population in comparison to 77.99 and 82.14% when treated with sulfoxaflor alone in seasons 2021 and 2022, respectively.

Except the used mineral oil, the effect of the tested compounds was decreased at eight weeks after treatment, which may be due to lack of concentration. Decreasing the activity has differed among the tested insecticides. (Table 2).

Against the crawler stage of the treated *M. mangiferae* population, the tested insecticides showed the same trend of activity as the used mineral oil was the most effective, followed by sulfoxaflor and spirotetramat. They achieved 91.60 – 98.01%, 90.98 – 96.69% and 88.35 – 95.80% reduction ranges, respectively in 2021 treatment in non-systematic arrangement with the time of exposure in comparison to 91.13– 97.49%, 86.39 – 95.23% and 80.48 – 92.43% in 2022 treatment in the same array. Treatment with the botanical insecticide (Nimbecidine 0.03% azadirachtin) caused the lowest reduction in the crawler population with 68.65 - 76.67% reduction range in 2021 treatment, compared with 67.33 – 74.62% reduction range in 2022 treatment, respectively in non-systematic arrangement. On the other side, when mixed with spirotetramat (at half the application rate of both), the produced mixture gave a higher effect. After 8 weeks of treatment, the mixture significantly exceeded the effect of the synthetic insecticide with 92.09% and 86.53% reduction, compared with 88.35% and 80.48% in case of the used synthetic spirotetramat alone in 2.21 and 2022 seasons, respectively.

Except for the used Kz oil, the effect of all tested insecticides and mixtures was decreased at eight weeks after treatment, which may be referred to as their concentration loss. The results are shown in Table (3).

Table 2: Effect of the tested insecticides on adult females of *M. mangiferae* during 2021 and 2022 seasons; shown as average mortality%± SD.

Tested Insecticide	Reduction (mortality%) on *M. mangiferae* adult females at different exposure times (weeks after treatment)							
	Season 2021Treatment				Season 2022 Treatment			
	2	4	6	8	2	4	6	8
Spirotetramat	79.06± 2.12	88.01± 1.05	90.70± 0.94	81.49± 2.71	76.51± 3.61	86.62± 1.13	89.57± 2.49	81.35± 4.70
Spirotetramat + Nimbecidine	81.74± 3.86	90.93± 0.54	92.15± 1.06	86.12± 2.46	80.11± 0.76	88.27± 0.93	89.47± 1.05	84.02± 2.32
Sulfoxaflor	81.30± 0.59	91.36± 0.73	92.04± 0.89	77.99± 4.94	79.25± 2.12	88.04± 0.84	91.25± 1.02	82.14± 2.36
Sulfoxaflor + Nimbecidine	85.00± 1.22	92.76± 0.11	94.52± 0.94	89.29± 2.15	82.52± 1.34	90.63± 0.95	90.60± 1.07	86.82± 1.26
Nimbecidine	52.01± 2.93	65.31± 3.46	67.73± 3.24	53.75± 2.59	49.68± 3.97	63.93± 3.32	65.37± 4.33	50.32± 3.20
Mineral oil	88.42± 2.47	94.71± 0.88	96.34± 0.77	97.70± 0.88	90.69± 2.08	95.45± 1.94	96.40± 0.87	94.10± 2.01
LSD $_{0.05}$	3.03	2.20	2.6	3.82	4.17	2.78	3.33	4.07

ANOVA of some insecticides effects on *M. mangiferae* adult in 2021 and 2022 seasons.

Source of variance (SOV)	Degree of freedom (df)	Reduction % in adult population							
		Season 2021				Season 2022			
		2 WAT	4 WAT	6 WAT	8 WAT	2 WAT	4 WAT	6 WAT	8 WAT
Blocks	3	*	ns	ns	*	ns	ns	ns	ns
Pesticide	5	**	**	**	**	**	**	**	**
Error	15	-	-	-	-	-	-	-	-
Total	23	-	-	-	-	-	-	-	-
CV	-	2.57	1.67	1.69	3.13	3.61	2.16	2.54	3.38
R^2	-	0.98	0.99	0.99	0.98	0.97	0.98	0.97	0.98

*, significant difference at $p < 0.05$; **; high significant difference at $p < 0.01$; ns, not significant difference; CV, coefficient of variation and R^2: Coefficient of determination.

Table 3: Effect of the tested insecticides on crawler of *M. mangiferae* during 2021 and 2022 seasons; shown as average mortality%± SD.

Tested Insecticide	Reduction (mortality%) on *M. mangiferae* crawler at different exposure times (weeks after treatment)							
	Season 2021Treatment				Season 2022 Treatment			
	2	4	6	8	2	4	6	8
Spirotetramat	90.62± 0.90	94.27± 0.64	95.80± 0.78	88.35± 0.90	84.54± 3.04	89.46± 0.69	92.43± 1.16	80.48± 2.07
Spirotetramat + Nimbecidine	91.52± 1.10	92.09± 0.43	95.62± 0.46	92.09± 0.74	86.72± 0.72	90.23± 0.98	92.62± 0.65	86.53± 1.21
Sulfoxaflor	90.98± 1.69	95.66± 0.87	96.69± 0.53	93.17± 1.17	87.71± 1.98	93.40± 1.21	95.23± 1.84	86.39± 0.82
Sulfoxaflor + Nimbecidine	92.80± 0.92	95.80± 0.60	97.01± 0.72	94.13± 0.58	88.68± 0.75	92.83± 0.84	93.63± 1.43	87.60± 1.25
Nimbecidine	74.66± 3.35	68.65± 1.29	76.67± 1.74	73.58± 1.18	73.10± 2.63	67.33± 1.16	74.62± 2.20	70.54± 1.31
Mineral oil	91.60± 2.06	96.38± 1.01	96.78± 0.95	98.01± 0.75	91.13± 1.31	93.43± 1.32	94.77± 1.69	97.49± 1.29
$LSD_{0.05}$	3.05	1.27	1.47	1.37	3.03	1.61	2.10	2.09

ANOVA of some insecticides effects on *M. mangiferae* crawler in 2021 and 2022 seasons

Source of variance (SOV)	Degree of freedom (df)	Reduction % in crawler population							
		Season 2021				Season 2022			
		2 WAT	4 WAT	6 WAT	8 WAT	2 WAT	4 WAT	6 WAT	8 WAT
Blocks	3	*	ns	ns	*	ns	ns	ns	ns
Pesticide	5	**	**	**	**	**	**	**	**
Error	15	-	-	-	-	-	-	-	-
Total	23	-	-	-	-	-	-	-	-
CV	-	2.28	0.93	1.05	3.13	2.36	1.22	1.54	1.64
R^2	-	0.94	0.99	0.99	0.98	0.93	0.99	0.98	0.98

*, significant difference at $p < 0.05$; **; high significant difference at $p < 0.01$; ns, not significant difference; CV, coefficient of variation and R^2: Coefficient of determination.

All the tested insecticides (synthetic, botanical or their mixture) affected the first and the second instars of the *M. mangiferae* in a lesser degree compared with the other treated stages. Against the 1st instar, the used mineral oil (Kz Oil) proved to be the most effective with a reduction percent ranging from 88.34 – 93.45% in 2021 treatment and 84.14 – 93.66% in 2022 treatment in non-systematic arrangement with the exposure time after treatment. There was no significant difference between the two treatments. Sulfoxaflor was less effective with 81.87 – 89.18% and 77.65 – 89.55% reduction ranges in 2021 and 2022 treatments, respectively. Spirotetramat (movento) revealed reduction range of 79.49 – 88.91% and 80.35 – 90.12% in 2021 and 2022 treatments, respectively. All the tested compounds reduced the nymph 1st instar in non-systematic arrangement with the time of exposure after treatments. Nimbecidine (0.03% azadirachtin) caused the lowest reduction % in the first instar population with 43.35 – 63.71% and 43.74 – 61.01% reduction ranges in 2021 and 2022 treatments, respectively in the non-systematic arrangement. Different from the other stages, the first nymph instar population was potentially significantly reduced when the nimbecidine was mixed with spirotramat at low time intervals. The mixture achieved 81.81% and 90.16% after 2 and 4 weeks of treatment in comparison to 79.49% and 81.63% in the case of the spirotetramat alone after the same exposure time in 2021 experiment. The same trend of effect was obtained when mixed with sulfoxaflor as the mixture caused 84.83%, 93.36%, and 92.99% reduction in the first instar in comparison to 81.87%, 88.52%, and 89.18% reduction at 2, 4, and 6 weeks exposure time, respectively in 2021 treatment. The mixture caused 82.05% reduction compared with 77.65% in the case of the insecticide alone after 2 weeks of exposure. At other exposure times the effect was relatively similar in both cases (Table 4).

Table 4: Effect of the tested insecticides on first instar nymph of *M. mangiferae* during 2021 and 2022 seasons; shown as average mortality%± SD.

Tested Insecticide	Reduction (mortality%) on *M. mangiferae* first instar nymph at different exposure times (weeks after treatment)							
	Season 2021 Treatment				Season 2022 Treatment			
	2	4	6	8	2	4	6	8
Spirotetramat	79.49± 2.07	81.63± 1.57	88.91± 1.89	80.15± 1.58	80.35± 1.93	89.06± 1.86	90.12± 2.01	82.75± 2.01
Spirotetramat + Nimbecidine	81.81± 0.63	90.63± 0.92	90.16± 1.26	83.62± 1.04	78.55± 2.25	88.40± 1.68	85.79± 1.59	80.06± 2.78
Sulfoxaflor	81.87± 1.57	88.52± 1.24	89.18± 2.09	85.44± 1.34	77.65± 2.32	88.53± 1.97	89.55± 2.04	88.22± 1.44
Sulfoxaflor + Nimbecidine	84.83± 0.76	93.36± 0.57	92.99± 0.33	87.68± 1.54	82.05± 1.76	90.04± 0.66	88.95± 0.69	81.91± 1.89
Nimbecidine	63.71± 0.80	43.35± 3.34	58.31± 2.71	52.79± 6.11	61.01± 1.06	43.74± 5.82	54.38± 2.78	51.89± 5.13
Mineral oil	88.34± 2.32	91.46± 1.88	91.96± 0.78	93.45± 0.99	84.14± 1.32	93.03± 2.25	92.63± 1.45	93.66± 1.77
$LSD_{0.05}$	2.03	2.65	2.61	4.13	2.14	3.77	2.45	4.26

ANOVA of some insecticides effects on *M. mangiferae* 1st instar in 2021 and 2022 seasons

Source of variance (SOV)	Degree of freedom (df)	Reduction % in first instar population							
		Season 2021				Season 2022			
		2 WAT	4 WAT	6 WAT	8 WAT	2 WAT	4 WAT	6 WAT	8 WAT
Blocks	3	*	ns	ns	*	ns	ns	ns	ns
Pesticide	5	**	**	**	**	**	**	**	**
Error	15	-	-	-	-	-	-	-	-
Total	23	-	-	-	-	-	-	-	-
CV	-	1.69	2.16	2.03	3.41	1.84	3.04	1.95	3.54
R^2	-	0.98	0.99	0.99	0.97	0.98	0.99	0.99	0.97

*, significant difference at $p < 0.05$; **; high significant difference at $p < 0.01$; ns, not significant difference; CV, coefficient of variation and R^2: Coefficient of determination.

The same trend of the tested insecticide effect was noticed against the 2nd nymph instar of the treated insect population as they exhibited their lethal effects on it in a non-systematic arrangement with the time after treatment. The used mineral oil (Kz oil) appeared the most effective in reducing this instar population with 84.77 – 90.74% and 84.58 – 94.27% in 2021 and 2022 treatments, respectively. Sulfoxaflor was more effective than Spirotetramat with 76.93 – 86.81% and 76.14 – 88.80% in 2021 treatment and with 79.14 – 89.34% and 77.63 – 88.43% in 2022 treatment, respectively. The tested botanical insecticide was the less effective with reduction ranges in the treated second instar population equaled 35.86 – 62.45% and 39.16 – 59.80% in experiments of 2021 and 2022 seasons, respectively in non-systematic arrangement. Its mixture with spirotetramat at half application rates enhanced the reduction power of the treated population at all tested exposure times in 2021 season, while it caused fluctuated effects based on the exposure times in 2022 season experiment. With the sulfoxaflor, it gave the same results trend relatively (Table 5).

In general, the total *M. mangiferae* stages census was diminished because of treatments with the used six insecticidal treatments in the two seasons (2021 and 2022) treatments. The results were recorded in Table (6), from which it could be deduced that the used mineral oil overcame all other toxicants with 88.19 – 95.49% and 87.79 – 94.76% reduction ranges in 2021 and 2022 treatments, respectively in systematic arrangement with the exposure time. Both sulfoxaflor and Spirotetramat appeared highly effective with 83.75 – 92.22% and 81.53– 91.82% compared with 82.17 – 91.86% and 80.30 – 90.46% in treatments in 2021 and 2022, respectively in non-systematic-arrangement.

Table 5: Effect of the tested insecticides on second instar nymph of *M. mangiferae* during 2021 and 2022 seasons; Shown as average mortality%± SD.

Tested Insecticide	Reduction (mortality%) on *M. mangiferae* second instar nymph at different exposure times (weeks after treatment)							
	Season 2021Treatment				Season 2022 Treatment			
	2	4	6	8	2	4	6	8
Spirotetramat	76.14± 3.85	81.43± 1.40	88.80± 1.81	78.16± 1.10	77.63± 3.62	79.87± 4.25	88.43± 2.37	80.65± 2.27
Spirotetramat + Nimbecidine	80.42± 0.92	88.93± 2.17	90.90± 1.60	85.53± 1.37	76.35± 2.15	87.96± 0.56	84.86± 1.77	77.04± 1.93
Sulfoxaflor	76.93± 1.50	84.98± 1.27	86.81± 2.08	81.94± 2.10	79.14± 4.99	85.81± 1.40	89.34± 0.81	85.73± 1.33
Sulfoxaflor + Nimbecidine	82.86± 1.95	85.45± 1.48	93.17± 1.10	88.39± 1.86	79.66± 1.69	90.55± 0.81	86.07± 1.78	79.07± 3.04
Nimbecidine	62.45± 0.76	35.86± 8.51	53.81± 2.43	50.04± 2.84	59.80± 0.95	39.16± 2.99	53.44± 0.39	48.67± 2.05
Mineral oil	84.77± 3.27	90.04± 2.68	89.27± 2.42	90.74± 2.52	84.58± 1.71	92.52± 2.26	94.27± 1.85	94.03± 2.66
$LSD_{0.05}$	3.81	5.53	2.81	2.81	3.45	3.96	2.25	3.06

ANOVA of some insecticides effects on *M. mangiferae* 2nd instar in 2021 and 2022 seasons

Source of variance (SOV)	Degree of freedom (df)	Reduction % in second instar population							
		Season 2021				Season 2022			
		2 WAT	4 WAT	6 WAT	8 WAT	2 WAT	4 WAT	6 WAT	8 WAT
Blocks	3	*	ns	ns	*	ns	ns	ns	ns
Pesticide	5	**	**	**	**	**	**	**	**
Error	15	-	-	-	-	-	-	-	-
Total	23	-	-	-	-	-	-	-	-
CV	-	3.27	4.71	2.22	2.36	3.01	3.31	1.81	2.62
R^2	-	0.93	0.98	0.99	0.99	0.95	0.99	0.99	0.99

*, significant difference at $p < 0.05$; **; high significant difference at $p < 0.01$; ns, not significant difference; CV, coefficient of variation and R^2: Coefficient of determination.

Table 6: Effect of the tested insecticides on total *M. mangiferae* stages during 2021 and 2022 seasons; Shown as average mortality%± SD.

Tested Insecticide	Reduction (mortality%) on *M. mangiferae* total stages at different exposure times (weeks after treatment)							
	Season 2021Treatment				Season 2022 Treatment			
	2	4	6	8	2	4	6	8
Spirotetramat	82.17± 1.78	87.62± 0.45	91.86± 1.08	83.00± 0.93	80.30± 2.17	86.66± 1.01	90.46± 0.67	81.36± 1.54
Spirotetramat + Nimbecidine	84.56± 0.31	90.89± 0.62	92.75± 0.42	87.59± 0.65	80.97± 0.82	88.90± 0.38	88.74± 0.73	81.79± 1.37
Sulfoxaflor	83.75± 1.78	91.12± 0.34	92.22± 1.07	86.21± 0.60	81.53± 2.59	89.40± 0.74	91.82± 1.05	85.72± 0.83
Sulfoxaflor + Nimbecidine	86.99± 0.45	92.60± 0.31	94.84± 0.38	90.54± 0.72	83.62± 0.41	91.18± 0.47	90.22± 0.22	83.63± 0.71
Nimbecidine	64.29± 1.46	56.13± 1.35	66.31± 0.83	59.96± 0.91	62.35± 1.36	54.96± 1.38	63.58± 1.18	55.59± 1.04
Mineral oil	88.19± 1.02	93.74± 1.20	94.22± 0.87	95.49± 0.12	87.79± 0.45	93.65± 0.62	94.56± 0.74	94.76± 1.27
LSD	1.34	1.20	1.09	1.07	1.86	1.26	0.98	1.48

ANOVA of some insecticides effects on *M. mangiferae* total stages in 2021 and 2022 seasons

Source of variance (SOV)	Degree of freedom (df)	Reduction % **in total stages population**							
		Season 2021				**Season 2022**			
		2 WAT	**4 WAT**	**6 WAT**	**8 WAT**	**2 WAT**	**4 WAT**	**6 WAT**	**8 WAT**
Blocks	3	*	ns	ns	*	ns	ns	*	*
Pesticide	5	**	**	**	**	**	**	**	**
Error	15	-	-	-	-	-	-	-	-
Total	23	-	-	-	-	-	-	-	-
CV	-	1.09	0.93	0.82	0.85	1.55	0.99	0.75	1.22
R^2	-	0.99	1.00	1.00	1.00	0.98	0.99	1.00	0.99

*, significant difference at $p < 0.05$; **; high significant difference at $p < 0.01$; ns, not significant difference; CV, coefficient of variation and R^2: Coefficient of determination.

Nimbecidine appeared the least effective insecticide with reduction ranges of the treated total population equaled 56.13 – 66.31% and 54.96 – 63.58% in the non-systematic arrangement in seasons 2021 and 2022, respectively. Treatment with a tank mixture of Spirotetramat and Nimbecidine at the half application rate of each of them significantly increased the activity to 84.56%, 90.89%, 92.75% and 87.59% reduction comparing with 82.17%, 87.62%, 91.86% and 83.00% reduction in case of Spirotetramat alone at its total application rate after 2, 4, 6 and 8 weeks exposure, respectively in 2021 treatment. The effect was so closer in the two cases in 2022 treatment. Tank mixing of nimbecidine with Sulfoxaflor behaved similarly to that with spirotramat as the reduction percent was 86.99%**,** 92.60%**,** 94.84% and 90.54%, comparing with 83.75%, 91.12%, 92.22% and 86.21% after 2, 4, 6 and 8 weeks exposure, respectively in 2021 treatment in case of the mixture and the insecticide itself, respectively. In the 2022 treatment the mixture was more effective than the tested sulfoxaflor alone even at its full application rate after 2 and 4 weeks of exposure time.From the obtained results, it could be concluded that the use of mineral oil was the most effective against all the *M. mangiferae* stages with continuous high activity even to 8 weeks of treatment, followed by the mixture of the used botanical insecticide with sulfoxaflor, sulfoxaflor, the mixture of the used botanical insecticide with Spirotetramat. Spirotetramat and the used botanical insecticide alone.

All of these differences in the effect are due to different modes of action of the applied insecticides, which may control the time required to kill the treated insect stage but all of the tested insecticides persuaded us for their satisfactory activity even after only two weeks of treatment reducing each of the treated insect stage at least to more than 70%, reaching more than 90 % in some cases.

Mineral oil controls the insect stages by blocking the respiratory system openings (suffocation effect) (Cook *et al*. 2004; Martín *et al*. 2004) and so oils suffocate the full range of scale developmental stages on leaves or wood more than on fruits because the comparatively smooth and uniform fruit surface than leaves or wood. Sulfoxaflor has a mode of action as a new nAChRs modulating insecticide (Culter *et al*. 2013). It binds to nAChR in place of acetylcholine acting as an allosteric activator of nAChR causing uncontrolled nerve impulses, followed by muscle tremors, paralysis, and finally death (Bacci, *et al*., 2018). Spirotetramat insecticide exhibits its effect by targeting acetyl-CoA carboxylase interrupting the lipid biosynthesis that reduces the fecundity of sucking insects upon foliar applications (Ke *et al*. 2010). So, it affects all of the treated insect stages nearly similar as a lipid biosynthesis inhibitor.

The nimbecidine mode of action includes antifeedant behavior that differed among species, adult sterility, and insect growth regulation, which are more consistent with delayed moults. Azadirachtin is the main biologically active component of neem-derived insecticides, although several other limonoids in complete neem seed oil with similar insecticidal properties. Complete neem seed oil may be more effective than purified azadirachtin. This is attributed to increased penetration of the insect cuticle by the oil and unique components of complete neem oil which affect insecticide efficacy (Stark and Walter, 1995). These effects are categorized as direct effects on cells and tissues and indirect effects exerted via the endocrine system (Mordue and Nisbet, 2000). Also, of course, the suffocation effect is faster than the inhibitory effect on the nervous system and so, the used Mineral oil appeared the fastest in its effect, followed by the other two tested insecticides.

As a conclusion, the tested insecticides can be arranged according to their reduction effect on all of the treated insect stages as follows:

The mineral oil (Kz oil) appeared the most effective, followed by the mixture of Nimbecidine® 0.03% azadirachtin at 250 ml/100 L and Sulfoxaflor

(Isoclast) 50% WG at 62.5 gm/ 200 L; Sulfoxaflor (Isoclast) 50% WG at 125 gm/ 200 L; the mixture of Nimbecidine® 0.03% at 250 ml/ 100 L and Spirotetramat (Movento) 10% SC at 20 ml/ 200 L; Spirotetramat (Movento) 10% SC at 40 ml/ 200 L and Nimbecidine® 0.03% (azadirachtin) at 500 ml/ 100 L.

These findings impressed us because adding the commercial botanical insecticide (Nimbecidine® 0.03% azaderachtin) at its half application rate enhanced the activity of the synthetic insecticides at their half application rates, which reflects high activity with the low harmful impact of the environment and non-target biota. Also, environmentally, the mineral oil is less harmful than the two other insecticides, so it will be preferable to control this insect.

REFERENCES

Abd-Rabou, S. and Evans G. A. (**2018**). The Mango Shield scale, *Milviscutulus mangiferae* (Green) (Hemiptera: Coccidae). A new invasive soft scale in Egypt. *Acta Phytopathologica et Entomologica Hungarica*, **53 (1)**: 91-96.

Atalla, F.A., Kwaiz F.A., Attlla A. R. (**2007**). Seasonal abundance of the mango soft scale insect, *Kilifia acuminate* (Signoret) (Hemiptera: Coccidae) and its parasitoids in Qalubyia Governorate, Egypt. *Bull. Soc. Ent. Egypt*., **84**: 103-110.

Attia, S. A., El-Sayid M. I. and Abd-ELAziz S.Y. (**2018**). Abundance and generation determination of the mango shield scale, *Milviscutulus mangiferae* (Green) (Coccidae: Homoptera) an Invasive Coccid Infesting Mango Orchards at Qaliobiya Gevernorate. *J Plant Prot. And Path., Mansoura Univ.*, **9 (3)**: 209-213.

Bacci, L., Convertini S. and Rossaro B. (**2018**). A review of sulfoxaflor, a derivative of biological acting substances as a class of insecticides with a broad range of action against many insect pests. *Journal of Entomological and Acarological Research*, **50**: 7836.

Bakry, M. M. S., Moussa S. F. M., Mohamed G. H., Abd-Rabou S., El-Amir S. M. (**2013**). Observations on the population density of the mango soft scale insect, *Kilifia acuminate* (Hemiptera: Coccidae) infesting mango trees at Armant district, Qena Governorate, Egypt. *Egypt. J Agric. Res*., **91(3)**: 113-135.

Bilal, A., Rizwan M., Sabir A. M., Gogi M. D., Farooq M.A. and Jamal A. (**2020**). Lethal and sublethal effects of clothianidin, imidacloprid and sulfoxaflor on the wheat aphid, *Schizaphis graminum* (Hemiptera: Aphididae) and its coccinellid predator, *Coccinella septempunctata*. *International Journal of Tropical Insect Science* https://doi.org/10.1007/s42690-020-00212-w

Cook J., Mercurio P., Burns K. A., Negri A. (**2004**). Testing the ecotoxicology of vegetable versus mineral based lubricating oils: 1. Degradation rates using tropical marine microbes. *Environmental Pollution*, **129 (2)**: 165 - 173.

CoStat, Ver. 6.311 (**2005**). Cohort software798 light house Ave. PMB320, Monterey, CA93940, and USA. email: info@cohort.com and Website: http://www.cohort.com/DownloadCoStatPart2. html

Gomez, K. A., and Gomez, A. A. (**1984**). Statistical procedures for agricultural research. John wiley & sons.

Culter, P., Slater S., Edmunds A. J., Maienfisch P., Hall R. G., Early F. G., Pitterna T., Pal S., Paul V. L., Goodchild J., Blacker M., Hagmann L., Crossthwalte A. J. (**2013**). Investigating the mode of action of sulfoxaflor, a fourth generation neonicotinoids. *Pest Management Science*, **69 (5)**: 607 - 619.

El-Baradey, W. M. M., Bakry M. M. S., El-Zoghby I. R. M. (**2020**). Population dynamics of the mango shield scale, *Milviscutulus mangiferae* (Green) on mango trees in Kafr El-Sheikh Governorate, Egypt. *International Journal of Research in Agriculture and Forestry*, **7 (4)**: 15-24.

Grimshaw, J. F. and Donaldson J. F. (2007). New record of mango shield scale, *Milviscutulus mangiferae* (Green) (Hemiptera: Coccidae) and *Brevennia rehi* (Lindinger) (Hemipter: Pseudococcidae) in north Queensland. *Austral Entomology*, 46 (2): 96–98.

Hassan, A. S., Nabil H. A., Shahein A. A., Hammad K. A. A. (**2012**). Some ecological aspects of *Kilifia acuminate* (Hemiptera: Coccidae) and its parasitoids on mango trees at Sharkia Governorate, Egypt. *Egypt. Acad. J Biolog. Sci*., **5 (3)**: 33-41.

Henderson C. F. and Tilton E. W. (**1955**). Tests with acaricides against the brown wheat mite. *Journal of Economic Entomoogy*, **48**: 157-161.

Karar H., Arif M. J., ArshadM., Ali A. and Abbas Q. (**2015**). Resistance/ susceptibility of different mango cultivars against mango mealy bugs (*Drosicha mangiferae* G) *Pak. J. Agri. Sci.*, **52** (**2**): 365-375.

Kasuya E, **2000**. Kin-biased dispersal behaviour in the mango shield scale, *Milviscutulus mangiferae*. *Animal Behaviour*, **59**: 629-632.

Ke, S., Sun T., Zhang Z., Zhang Y-N., Liang Y., Wang K., Yang Z. (**2010**). Spirodiclofen analogues aspotential lipid-biosynthesis inhibitors: a convenient synthesis, biological evaluation and structure activity relationship. *Bulletin of the Korean Chemical Society*, **31 (8)**: 2315 - 2321.

Malumphy, C. (**2018**). Two species of whitefly and six species of scale insect (Hemiptera: Aleyrodidae and Coccoidea), new for Antigua. *Lesser Antilles. Entomologist' s Monthly Magazine*, **154**: 53-59.

Martín, B., Varela J. and Cabaleiro C. (**2004**). Effects of various oils on survival of *Myzus persicae* Sulzer and its transmission of cucumber mosaic virus on pepper. *Journal Horticultral Science Biotechnology*, **79 (6)**: 855-858.

Mohamed, L. Y. H. (**2020**). Seasonal abundance on the mango shield scale *Milviscutulus mangiferae* (Hemiptera: Coccidae) infesting mango trees at Ismailia Governorate, Egypt. *Egypt. J. Plant Prot. Res. Inst.*, **3 (2)**: 580 -588.

Mordue (Luntz), A. J. and A. J. Nisbet (**2000**). Azadirachtin from the Neem Tree *Azadirachta indica*: Its Action against insects. An. Soc. Entomol. Brasil **29 (4)**: 615-632.

Nabil, H. A. (**2013**). Relationship between *Kilifia acuminate* (Signoret) and chlorophyll percentage loss on mango leaves *J of Entomology*, **10 (2)**: 110-114.

Rezk, M. and Abdel-Aty, A. S. (**2023**). Control of the Mango Shield Scale, *Milviscutulus Mangiferae* (Green) by Two Bio Rational Insecticides. *Alexandria Science Exchange Journal*, **44 (4)**: 727-734

Schmutterer H. (**1995**). The Neem Tree Azadirachta indica A. Juss. and other Meliaceous Plants. VCH Verlagsgesellschaft mbH,Weinheim, Germany

Soliman, M. M. M., Kwaiz F. A. M., Shalby S. E. M. (**2007**). Efficiency of certain miscible oils and chlorpyriphos methyl insecticide against the soft scale insect, *Kilifia acuminata* Signoret (Homoptera: Coccidae) and their toxicities on rats. *Archives of Phythetopathology and Plant Protection*, **40 (4)**: 237-245.

Stark, J. D. and J. F. Walter (**1995**). Neem oil and neem oil components affect efficacy of commercial neem insecticides. *J Agric Food Chem* **43**:507-512.

Upadhyay, V., Dinesh R., Meenakshi R., Prateeksha M. and Pandey A. K. (**2014**). *Verticillium lecani* (Zimm.): A potential entomopathogenic fungus. *International Journal of Agriculture, Environment & Biotechnology Citation: IJAEB*, **7 (4)**: 719-727.

الملخص العربي

تقوية نشاط مبيدى الإسبيروتترامات spirotetramat و السالفوكسافلور sulfoxaflor على حشرة المانجو القشرية (Green) *M. mangiferae* حقليا بالخلط مع مبيد النيمبيسيدين nimbecidine الحيوى

محمد رزق[1]، أحمد صبرى عبد العاطى[2]

[1] قسم الحشرات القشرية والبق الدقيقى، معهد بحوث وقاية النبات، مركز البحوث الزراعيـــة ، جمهوريـــة مصـــر العربية

[2] قسم كيمياء وتقنية المبيدات، كلـــية الزراع ، ٢١٥٤٥ – الشاطبى – جامعة الأسكندرية– جمهورية مصر العربية

تم إختبار ست معاملات لمبيدات حشرية مختلفة فى طريقة إحداث الفعل السام mode of action على جميع أطوار حشرة المانجو القشرية (Green) *Milviscutulus mangiferae* على أشجار المانجو العائلة لها. هدفت هذه الدراسة إلى المقارنة بين المبيدات المستخدمة نحو إختزال عدد الأطوار المختلفة بالإضافة إلى التعداد الكلى لأفراد العشيرة المعاملة لهذه الحشرة محل الدراسة. المبيدات المستخدمة هى الـــ سبيروتترامات (موفينتو (Spirotetramat, Movento,10% SC) ومبيد الـــ سالفوكسافلور (أيزوكلاست) (Sulfoxaflor, Isoclast, 50% WG) والزيت المعدنى

(KZ Oil, 95% EC). تم إضافة (خلط) مبيد النيمبيسيدين Nimbecidine® 0.03% (Azadirachtin) الحيوى مع كلا المبيدين (الـــ سبيروتترامات (موفينتو) والـــ سالفوكسافلور (أيزوكلاست)) على حدة بنصف معدل التطبيق الحقلى لكل منها لمعرفة تأثير هذا الخليط على الفعالية تجاه الحشرة المعاملة.

تأثرت أطوار هذه الحشرة المعاملة بصورة مختلفة حيث جاء التأثير على الأطوار المختلفة لهذه الحشرة كدالة فى كل من الطور المعامل، المبيد المطبق بالإضافة إلى زمن التعرض للمبيد المختبر مع إستمرار النشاط العالى لهذه المركبات حتى ٨ أسابيع بعد المعاملة. يمكن إرجاع إختلاف درجة التأثير بين المبيدات المستخدمة إلى إختلاف طريقة إحداث الفعل السام لها. وجد أيضا أن الطور الأول والثانى للحوريات المعاملة Nymph ظهرا أقل تأثراً من بقية الأطوار (الحشرة الكاملة والطور الزاحف) فى كل المعاملات المطبقة، كما ظهرت النسبة المئوية لإختزال أعداد الأطوارالمختلفة وكذلك تعداد العشيرة الكاملة متزايدة بصورة غير ثابتة التغير مع زيادة زمن التعرض للمبيد.

جاء الزيت المعدنى (KZ Oil, 95% EC) فى مقدمة المبيدات المعاملة تأثيرا على الأطوار المختلفة بالإضافة إلى التعداد الكلى لأفراد العشيرة المعاملة لهذه الحشرة يليه مخلوط مبيدى النيمبيسيدين Nimbecidine® 0.03% (Azadirachtin) الحيوى مع مبيد الـــ سالفوكسافلور (أيزوكلاست) بنصف معدل التطبيق لكل منهما، يليه الـــ سالفوكسافلور (أيزوكلاست) بالمعدل الكامل للتطبيق له ثم يليه مخلوط مبيدى النيمبيسيدين Nimbecidine® 0.03% (Azadirachtin) الحيوى مع مبيد الـــ سبيروتترامات (موفينتو) بنصف معدل التطبيق لكل منهما ثم يليه مبيد الـــ سبيروتترامات (موفينتو) بمعدل التطبيق الكامل له ثم يليه المبيد الحيوى النيمبيسيدين Nimbecidine® 0.03% (Azadirachtin) على معدل التطبيق الكامل له.

من النتائج المتحصل عليا ثبت لدينا أن خلط المبيد الحيوى Nimbecidine® 0.03% azadirachtin مع المبيدات الصناعية المطبقة بنصف معدل التطبيق لكل منهما أدى إلى تقوية و زيادة التأثير على حشرة المانجو القشرية محل الدراسة بأطوارها المختلفة وكذلك على تعدادها الكلى مما يفيد فى مكافحة هذه الحشرة و أيضا يقلل من التركيز المطبق للمبيدات الصناعية والذى ينعكس تأثيره الإيجابى فى الحفاظ على البيئة بأوجهها المختلفة من التلوث و كذلك السمية المباشرة على الكائنات غير المستهدفة.