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Field Efficiency of Nano and Conventional Formulations of Certain Neonicotinoid Insecticides Against Oleander Scale Insect, *Aspidiotus nerii* Bouché (Hemiptera: Diaspididae) on Certain Olive Varieties

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ABSTRACT

The olive tree *Olea europaea* L. is attacked by numerous pests that affect yield quality and quantity. Oleander scales, *Aspidiotus nerii* Bouché (Hemiptera: Diaspididae) is considered one of the most important pests in plantation and reclamation areas in Egypt. Herein, under olive field conditions, two seasons of study (2017-2018 and 2018-2019) were undertaken to evaluate the efficiency of some nano-insecticide formulations of three neonicotinoid insecticides (acetamiprid, dinotefuran and thiamethoxam) in comparison with their conventional formulations against *A. nerii*. The foliar application of nanoformulations at the recommended rate (1X) of acetamiprid induced the highest average reduction percentage of *A. nerii* (100%) and more efficacy than dinotefuran (83.28%) and thiamethoxam (82.73%). Whereas thiamethoxam as (½ X) caused a highest average reduction percentage (100%) compared with acetamiprid (64.61%) and dinotefuran (82.50%). Plus, acetamiprid and thiamethoxam as (¼X) caused the highest average reduction percentage (80.07 and 85.72%) compared with dinotefuran (73.07%). Results indicated that all of nano formulations at (1X, ½X and ¼X) recommended rate were caused a high average reduction percentage compared with the conventional formulation (1X) which was (87.66, 81.11 and 60.88%) respectively. Furthermore, the efficacy and remaining effects of these nano formulations continued up to 21 days after treatment against *A. nerii*. The results of this study may strongly suggest the use of nano-neonicotinoid insecticide formulations in the application of the olive scale IPM pest program, but caution should be exercised with regard to the possible side effects of such formulations on other aspects of the environment.

INTRODUCTION

Olive, *Olea europaea* L. is one of the most economical horticultural crops in Egypt. Olive fruits are a valuable commodity worldwide; they are eaten whole, filled and sliced as table olives and olive oil produced from fruit milling and must be prepared under safe

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conditions according to international olive oil standardization (Tokuşoğlu *et al.*, 2010). In general, the olive species include several cultivars, such as "Chemlali" and "Coratina" or table olives such as "Kalamata" and "Teffahi" and double-purpose, such as "Picual" and "Manzanillo" for oil extraction. In contrast to other fruit trees, growers favor olive cultivation because of its tolerance to drought and salinity conditions, in addition to low fertilization needs. The cultivated area of olive trees in Egypt has rapidly expanded year after year. More than 61711 hectares (152491.28 feddans) were cultivated by olive during 2013 and reached 81039 hectares (200251.83 feddan) in 2017. The quantity of production reached about 541790 tons in 2013 and 927595 tons in 2017 (Faostat, 2019a,b).

Basically, many insect pests affect the quality and quantity of olive yield. These pests belong to Lepidoptera, Diptera, Coleoptera, Hemiptera, Orthoptera, and Thysanoptera (Spooner-Hart *et al*., 2007). In Egypt, olive trees are attacked by several species of insect pests, 15 arthropod species belonging to 14 genera, 9 families and 4 orders were found to be associated with olive groves in Egypt. The greatest number of arthropod species infesting olive was belonging to the order Homoptera (60%). However, 20%, 13.33% and 6.67% of the recovered species were belonging to orders Lepidoptera, Diptera and Coleoptera, respectively. The highest number of arthropod species attacking olive trees was belonging to the homopteran family Diaspididae (4 species) (El-Hakim and Helmy, 1982; Abou-Elhagag, 2004; Abd-Raboou and Ahmed, 2011; Abd-Ella *et al*., 2020).

Aspidiotus nerii Bouche (Hemiptera, Diaspididae) is a cosmopolitan plague known to occur in the tropical and subtropical regions of the world, particularly in the Mediterranean countries. It is a polyphagous insect pest associated with more than 100 plant families that have been reported (Einhorn *et al.*, 1998; Andersen *et al.*, 2010; Erol & Özgökçe, 2018). This scale insect is strongly polyphagous, targeting acacia, citrus (mainly lemon), mulberry, oleander, palm, olive, peach, plum, pear, kiwi, asparagus, carob, ivy, jojoba, and a wide variety of host plants and, It feeds on leaves, bark and fruits (Uygun & Elekçioğlu, 1998, Mourad *et al.*, 2001; Zappalà, 2001; Batsankalashvili *et al.*,2017; Abu Alloush, 2019). Leaf and stem infestations cause wilting and can decrease the photosynthetic area of the plants, resulting in lower yields. Fruit damage occurs in extreme infestations, where market value is affected by spotting and also by fruit deformity and this is seen in olives as green spots on purple fruits (Therios, 2008, CABI, 2020).

Pesticide applications in olive trees are sometimes necessary against some olive insect pests, such as *P. oleae* and scale insects (Iannotta, 2003). *A. nerii* can be regulated by the treatment of traditional pesticides such as insect growth regulators and organophosphates (Olivas *et al.*, 2011). Application of plant oil or insecticidal soap can significantly kill *A. nerii* when targeting the first instar in shade house conditions. Both plant oils and insecticidal soaps showed higher *A. nerii* mortality compared to untreated controls (Quesada & Sadof, 2017). Several reduced-risk insecticides (pyriproxyfen, chlorantraniliprole, spirotetramat and spiromesifen and), two broad-spectrum standards of insecticides (bifenthrin and dinotefuran) and horticultural oil were evaluated for English ivy (Quesada *et al.*, 2018). They stated that horticultural oil and bifenthrin recorded the best-integrated management against *A. nerii*. Whereas, spirotetramat, pyriproxyfen and spiromesifen recorded a significant reduction in the abundance of *A. nerii* when compared with the water treatment.

In this regard, neonicotinoids are the most recent principle type of pesticides with excellent power and systemic intervention to protect crops from piercing-sucking pests such as scale insects. Acetamiprid, imidacloprid, clothianidin, dinotefuran, nitenpyram, thiamethoxam, and thiacloprid are common names (Tomizawa *et al.*, 2007). They have lower mammalian toxicity, fewer issues with resurgence, environmental safety, selectivity for pest control and less toxicity to natural enemies. (Kunkel *et al.*, 1999). Neonicotinoids are broad-spectrum, systemic compounds that exhibit recreation against sucking pests (e.g.

aphids, whiteflies, leafhoppers, scale insects) and various species of flies and moths. These are readily absorbed by using flowers and act quickly, at low doses as in contrast to different insecticides (Nauen *et al.*, 1996).

Pesticides are essential inputs for improving crop productivity and preventing predominant biological failures. In recent years, the use of nanotechnology to create novel formulations has demonstrated gorgeous capacity in enhancing the effectivity and protection of pesticides. Further, the production of nano-based pesticide formulations (nanoparticles size 1-100 nm) aims to accurately release the required and adequate quantities of their active ingredients by means of controlled release mechanisms in response to environmental and biological demands. While the use of nanoparticles in agriculture is still controversial, many proprietary products have been produced that integrate nanomaterials, such as nano pesticides, nano fertilizers and nanosensors (Kah, 2015; Prasad *et al.*, 2017).

To our knowledge, there is a lack of information and data about the efficiency of nano and conventional formulations of neonicotinoid insecticides against olive scale insect pests. Thus, the aim of this work is to evaluate for the first time the field efficiency of nano and conventional formulations of certain neonicotinoid insecticides against Oleander scale insect, *A. nerii* on olive varieties picual, carotina and chemlali.

MATERIALS AND METHODS

1.Field Experiments:

Two seasons of study (2017-2018 and 2018-2019) were carried out to evaluate the efficiency of some nano-insecticide formulations of three neonicotinoid insecticides (acetamiprid, dinotefuran and thiamethoxam) in comparison with their conventional formulations on the oleander scale, *A. nerii*. These experimental trials were carried out at the Faculty of Agriculture Experimental Farm Assiut University, Assiut, Egypt all through two successive years. This farm is a rather mosaic agro-ecosystem characterized by means of remoted areas of olive.

2.Tested Insecticides, Structures and Application:

Tested commercial insecticides are listed in (Table 1) trade names, formulation types, common name (active ingredient %), and application rate, and their chemical structures are illustrated in (Fig.1). The doses of pesticides used in this study were based on the recommendation rate labeled.

The neonicotinoids tested (acetamiprid, dinotefuran, and thiamethoxam) were divided into three treated olive trees of each variety and three untreated as controls in a simple configuration. For the application, a single nozzle knapsack sprayer covering 200 liters per feddan (1 feddan = 0.42 hectare) was used. Insecticides were applied on November 1 (one spray) against olive scale insect pests during (2017-2018 and 2018-2019). Data for the evaluation of the efficacy and residual activity of these insecticides on the oleander scale, *A. nerii* population were reported on the stated days before and after treatment at 1, 7, 15 and 21 days after treatment,

Table 1: Descriptions of the pesticides used on the oleander scale, *A. nerii* under field conditions.

Common Name (a.i)	TradeName	Formulation type and % (a.i.)*	Company	Application dose
Acetamiprid	Mospilan®	20 % SP	NipponSodaLtd.	250 mg L^{-1}
Dinotefuran	Ochin®	20% SG	MitsuiChemicals	500 mg L^{-1}
Thiamethoxam	Actara®	25% WP	SyngentaAgro	250 mg L^{-1}

*SP: Soluble powder, SG: Soluble granules WP: Wettable powder

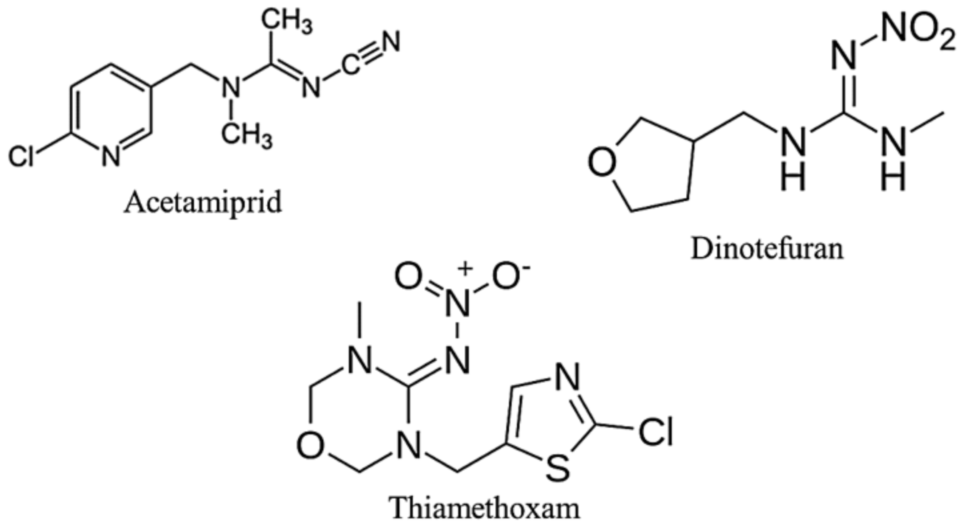

Figure 1: Structure of selected insecticides, neonicotinoids (acetamiprid, dinotefuran, and thiamethoxam) used against the Oleander scale, *A. nerii* under field conditions.

To determine the field efficiency (reduction %) of the examined insecticides (after 1, 7, 15 and 21 days of spraying) to calculate the reduction percentage in the oleander scale, *A. nerii* we used (Henderson & Tilton, 1955) equation:

$$\text{Reduction \%} = \left(1 - \frac{n\ in\ Co\ before\ treatment * n\ in\ T\ after\ treatment}{n\ in\ Co\ after\ treatment * n\ in\ T\ before\ treatment}\right) * 100$$

Where: Co= control, T= treatment, n = insect population

3.Field Efficiency of Nano and Traditional Formulations Against the Oleander Scale, *A. nerii:*

The traditional formulation of neonicotinoid (acetamiprid, dinotefuran, and thiamethoxam) insecticides was used according to the recommended dose (Table 1). The nano-formulations were applied at the same recommended rate and are 1/4 and 1/2 using Knapsack hand spray fitted with one nozzle and the untreated control olive trees were treated with water. Insecticides were applied on November 1 (one spray) against the oleander scale, *A. nerii* during the 2018-2019 season.

Nano Preparation: The nano insecticides were prepared by Prof. Dr. Ali A. Othman, Physics Department, Faculty of Science, University of Assiut, and based on the Top-Down strategy in accordance with the high-energy ball milling method (FRITSCH, Pulversette- 2) was utilized for the reduction of size (Yadav & Vasu, 2016). The mean crystallite size dimension (D) was once determined via Scherrer's method (Scherrer, 1918): $D = 0.9\ \lambda / \beta.\cos\theta$, where λ is x-ray radiation wavelength (λ= 0.1506 nm for k α x-rays), β is full width at half maximum (FWHM), and θ is the Bragg's angle of diffraction. The insecticides average crystallite size (D) was from 12.4 ±1.1 to 23.2±1.1 nm.

4.Presentation of Data and Statistical Analyses Methods:

Results had been analyzed with the use of one-way ANOVA and presented as mean ± Standard Error of Mean (S.E.M). Means were separated through Duncan's Multiple Range Test (DMRT) and Tukey's Multiple Comparison Test (TMCT). Statistical analysis and figures have been completed with the usage of the Graph Pad Prism 5TM program (San Diego, CA) and SPSS version 18 software.

RESULTS AND DISCUSSION

1.Field Efficiency of Conventional Formulation of Three Neonicotinoid Insecticides Against *A. nerii*:

Based on the field study to determine the efficacy of three neonicotinoid insecticides acetamiprid, dinotefuran and thiamethoxam (conventional formulation) against oleander scale insect, *A. nerii* on some olive varieties picual, carotina and chemlali through 2017-2018 and 2018-2019 seasons and the results are presented in Tables (2 and 3).

Table 2. Field efficiency of certain neonicotinoid insecticides against the Oleander scale insect, *A. nerii* on olive varieties picual, coratina and chemlali at 1, 7, 15 and 21 days after treatment (DAT) during 2017-2018 season.

Insecticides	Reduction (%) of *A. nerii* ± SE				Avg. Red. (%)
	1DAT	7DAT	15DAT	21DAT	
Picual variety					
Acetamiprid	62.22 ± 1.55b	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**90.56 ± 0.4 b**
Dinotefuran	100 ± 0.0a	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**100 ± 0.0 a**
Thiamethoxam	100 ± 0.0a	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**100 ± 0.0 a**
Coratina variety					
Acetamiprid	57.14±1.34a	100.0±0.0a	100.0±0.0a	100 ±0.0 a	**89.29±0.34a**
Dinotefuran	47.43±1.55b	81.53±1.15 b	87.98±1.11b	100 ± 0.0 a	**79.24±0.95b**
Thiamethoxam	23.08±1.78c	100 ± 0.0 a	100 ± 0.0a	100 ± 0.0 a	**80.77±0.45a**
Chemlali variety					
Acetamiprid	42.86±1.14b	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**85.72±0.29a**
Dinotefuran	12.61±1.34c	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**78.15±0.34b**
Thiamethoxam	51.02±1.53a	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**87.67±0.38a**

Means followed by the same superscript letter(s), within the same column are non-significantly different ($P \leq 0.05$) according to DMRT.

Results in Table (2) indicate that neonicotinoid insecticide treatments caused a significant reduction in oleander scale insect, *A. nerii* population compared to the control in 2017-2018 season. Neonicotinoid insecticides, acetamiprid, dinotefuran and thiamethoxam caused an average reduction percentage of oleander scale insect, *A. nerii* which was (90.56, 100 and 100 %), (89.29, 79.24 and 80.77%) and (85.72, 78.15 and 87.67%) on olive picual, coratina and chemlali varieties respectively at a different exposure. During 2018-2019 season, similar results were obtained which acetamiprid, dinotefuran and thiamethoxam caused an average reduction percentage in *A. nerii* population by (87.66, 81.11 and 60.88%), (80.47, 71.68 and 80.58%) and (75.65, 63.61 and 80.0 %) on olive picual, coratina and chemlali varieties respectively (Table 3). These results indicated that acetamiprid and dinotefuran exhibited a highly significant reduction compared with thiamethoxam on picual variety. Whereas, acetamiprid and thiamethoxam were more effective compared to dinotefuran on coratina and chemlali varieties. Our results indicated that foliar application of conventional acetamiprid, dinotefuran and thiamethoxam recorded a significant reduction in *A. nerii* population at 1, 7, 15 and 21 DAT compared to the untreated control on different olive varieties during both seasons. Furthermore, the residual effects and efficiency of acetamiprid, dinotefuran and thiamethoxam persisted up to 21 DAT against *A. nerii* in both seasons.

The reduction percentage of the population increased over time this may be due to the ability of neonicotinoid insecticides to penetrate the plant tissues and persistence on the leaves and maybe the population of pests more sensitive to neonicotinoids. Many authors reported that the efficacy of different insecticides such as spiromesifen, pyriproxyfen, spirotetramat and chlorantraniliprole, two broad-spectrum insecticide standards (dinotefuran and bifenthrin) and horticulture oils, reduced the abundance of *A. nerii* when compared with the untreated control (Olivas *et al*., 2011; Quesada & Sadof, 2017; Quesada *et al*., 2018).

Table 3. Field efficiency of certain neonicotinoid insecticides against the oleander scale insect, *A. nerii* on olive varieties picual, coratina and chemlali at 1, 7, 15 and 21 days after treatment during 2018-2019 season.

Insecticides	**Reduction (%) of *A. nerii* ± SE**				**Avg. Red. (%)**
	1DAT	**7DAT**	**15DAT**	**21DAT**	
Picual variety					
Acetamiprid	71.43±1.15a	79.22±1.25b	100 ± 0.0 a	100 ± 0.0 a	**87.66±0.60a**
Dinotefuran	60.00±1.35b	100.0±0.0a	64.44±1.55 b	100± 0.0 a	**81.11±0.73a**
Thiamethoxam	30.00±1.11c	49.09±1.22c	64.44±1.41 b	100 ± 0.0 a	**60.88±0.94b**
Coratina variety					
Acetamiprid	57.81±0.50b	69.64±1.25a	94.44±1.53a	100 ± 0.0 a	**80.47±0.82a**
Dinotefuran	37.50±1.33c	71.43±1.14a	77.78±0.98b	100 ± 0.0 a	**71.68±0.86b**
Thiamethoxam	67.59±1.44a	62.96±1.19b	91.77±1.50a	100 ± 0.0 a	**80.58±1.03a**
Chemlali variety					
Acetamiprid	43.33±1.21a	74.07±1.78b	85.19±0.95b	100 ± 0.0 a	**75.65±0.99a**
Dinotefuran	43.33±1.53a	48.15±0.85c	62.96±1.14c	100 ± 0.0 a	**63.61±0.88b**
Thiamethoxam	20.0±1.35b	100 ± 0.0 a	100 ± 0.0a	100 ± 0.0 a	**80.00±0.34a**

2.Field Efficiency of Nanoformulation of Neonicotinoids Against *A. nerii*:

Results of the field efficiency of nanoformulations (recommended rate) of the neonicotinoid insecticides acetamiprid, dinotefuran and thiamethoxam against the oleander scale insect, *A. nerii* on olive varieties picual, coratina and chemlali at 1, 7, 15 and 21 days after treatment (DAT) during 2018-2019 season are shown in Table 4. Acetamiprid prevailed a high significant reduction percentage in oleander scale insect population, (100, 100, 100 and 100%), (55.73, 100, 90.74 and 100%) and (44.0, 82.22, 82.22 and 100%) at 1, 7, 15 and 21 DAT on olive picual, coratina and chemlali varieties respectively. Dinotefuran caused (30.0, 100, 100 and 100%), (68.75, 79.59, 84.13 and 100%) and (54.67, 100, 79.26 and 100 %) at 1, 7, 15 and 21 DAT on olive picual, coratina and chemlali varieties respectively. Whereas thiamethoxam caused (60.0, 70.91, 100 and 100%), (68.75, 64.29, 100 and 100%) and (52.94, 100, 100 and 100 %) at 1, 7, 15 and 21 DAT on olive picual, coratina and chemlali varieties respectively. Our results indicated that nanoformulations at a recommended rate of acetamiprid, dinotefuran and thiamethoxam caused the highest average reduction percentage in *A. nerii* population which was (100, 82.50 and 82.73%), (86.62, 83.12 and 83.26%) and (77.11, 83.48 and 88.24%) compared with the conventional formulation which was (87.66, 81.11 and 60.88%), (80.47, 71.68 and 80.58%) and (75.65, 63.61 and 80.0%) on olive picual, coratina and chemlali varieties respectively during 2018-2019 season (Table 4). These results indicated that acetamiprid and dinotefuran were more effective than thiamethoxam on picual variety, whereas acetamiprid and thiamethoxam were more effective than dinotefuran on coratina and chemical varieties against *A. nerii*.

Generally, it was observed that the foliar application of nanoformulations at the recommended rate of acetamiprid, dinotefuran and thiamethoxam caused a significant reduction compared with their conventional formulations in the oleander scale insect population at 1, 7, 15 and 21 DAT on different olive varieties. The residual effects and efficiency of these nano-formulations continued up to twenty-one days after treatment against *A. nerii*. through this season.

Table 4. Field efficiency of nanoformulations (1X) recommended rate of certain neonicotinoid insecticides against the oleander scale insect, *A. nerii* on olive varieties picual, coratina and chemlali at 1, 7, 15 and 21 days after treatment through 2018-2019 season.

Insecticides	**Reduction (%) of *A. nerii* ± SE**				**Avg. Red. (%)**
	1DAT	**7DAT**	**15DAT**	**21DAT**	
Picual variety					
Acetamiprid	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**100 ± 0.0a**
Dinotefuran	30.0±1.33c	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0a	**82.50±0.33b**
Thiamethoxam	60.00±1.40b	70.91±1.53b	100 ± 0.0 a	100 ± 0.0a	**82.73±0.73b**
Coratina variety					
Acetamiprid	55.73±1.55b	100.0±0.0a	90.74±1.40b	100 ± 0.0 a	**86.62±0.74a**
Dinotefuran	68.75±1.25a	79.59±1.33b	84.13±1.50b	100 ± 0.0 a	**83.12±1.02a**
Thiamethoxam	68.75±1.15a	64.29±1.53c	100 ± 0.0 a	100 ± 0.0 a	**83.26±0.67a**
Chemlali variety					
Acetamiprid	44.00±1.11b	82.22±1.35b	82.22±1.35b	100 ± 0.0a	**77.11±0.95b**
Dinotefuran	54.67±1.55a	100 ± 0.0 a	79.26±1.41b	100 ± 0.0a	**83.48±0.74a**
Thiamethoxam	52.94±1.33a	100 ±0.0 a	100 ± 0.0a	100 ± 0.0a	**88.24±0.33a**

Data in Table (5) show that, the comparison between the field efficiency of nano at (1X, ½ X and ¼ X) and conventional formulations (1X) recommended rate of acetamiprid, dinotefuran and thiamethoxam against the oleander scale insect, *A. nerii* on olive variety picual at 1, 7, 15 and 21 days after treatment during 2018-2019 season. Acetamiprid as nano formulation recorde a highest significant reduction in *A. nerii* population, (1X) (100, 100, 100 and 100%), (½X) (0.0, 58.44, 100 and 100%) and (¼X) (41.18, 100, 79.08 and 100%) compared with conventional formulation (1X) (71.43, 79.22, 100 and 100%) at 1, 7, 15 and 21 DAT respectively. As well, dinotefuran nano formulation caused a highest significant reduction in oleander scale insect population, (1X) (33.11, 100, 100, and 100%), (½X) (30.0, 100, 100, and 100%) and (¼X) (58.82, 70.05, 63.40 and 100%) compared with conventional formulation (1X) (60.0, 100, 64.44, and 100%) at 1, 7, 15 and 21 DAT respectively. Nano-thiamethoxam listed the same trend of reduction which caused a highest significant reduction (1X) (60.0, 70.91, 100 and 100%), (½X) (100, 100, 100 and 100.0%) and (¼X) (42.86, 100, 100 and 100%) compared with conventional formulation (1X) (30.0, 49.09, 64.44 and 100%) at 1, 7, 15 and 21 DAT respectively.

Table 5. Field efficiency of nano (1X, ½ X and ¼ X) and conventional (1X) formulations recommended rate of certain neonicotinoid insecticides against the oleander scale insect, *A. nerii* on olive variety picual at 1, 7, 15 and 21 days after treatment (DAT) during 2018-2019 season.

Insecticides	**Reduction (%) of *A. nerii* ± SE**				**Avg. Red. (%)**
	1 DAT	**7 DAT**	**15 DAT**	**21DAT**	
	Conventional (1X) recommended rate				
Acetamiprid	71.43±1.15a	79.22±1.25b	100.0±0.0a	100 ± 0.0 a	**87.66±0.60a**
Dinotefuran	60.00±1.35b	100.0±0.0a	64.44±1.55b	100 ± 0.0 a	**81.11±0.73a**
Thiamethoxam	30.00±1.11c	49.09±1.22c	64.44±1.41b	100 ± 0.0 a	**60.88±0.94b**
	Nano-formulation (1X) recommended rate				
Acetamiprid	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**100.0±0.0a**
Dinotefuran	33.11±1.33c	100 ± 0.0 a	100 ± 0.0 a	100 ±0.0 a	**83.28±0.33b**
Thiamethoxam	60.00±1.40b	70.91±1.53b	100 ± 0.0 a	100 ± 0.0 a	**82.73±0.73b**
	Nano-formulation (½ X) recommended rate				
Acetamiprid	0.00±0.0c	58.44±1.55b	100.0±0.0a	100.0±0.0a	**64.61±0.39c**
Dinotefuran	30.00±1.38b	100.0±0.0a	100.0±0.0a	100.0±0.0a	**82.50±0.36b**
Thiamethoxam	100.0±0.0a	100.0±0.0a	100.0±0.0a	100.0±0.0a	**100.0±0.0a**
	Nano-formulation (¼ X) recommended rate				
Acetamiprid	41.18±1.25b	100 ± 0.0 a	79.08±1.55b	100 ± 0.0 a	**80.07±0.70a**
Dinotefuran	58.82±1.11a	70.05±0.98b	63.40±1.67c	100 ± 0.0 a	**73.07±0.94b**
Thiamethoxam	42.86±1.35b	100 ± 0.0 a	100 ± 0.0 a	100 ± 0.0 a	**85.72±0.34a**

In addition, it was observed that nanoformulations at the recommended rate (1X) of acetamiprid induced the highest average reduction percentage of *A. nerii* (100%) and more efficacy than dinotefuran (83.28%) and thiamethoxam (82.73%). Whereas thiamethoxam as (½ X) caused the highest average reduction percentage (100%) compared with acetamiprid (64.61%) and dinotefuran (82.50%). Also, acetamiprid and thiamethoxam as (¼X) caused the highest average reduction percentage (80.07 and 85.72%) compared with dinotefuran (73.07%). Results indicated that all nanoformulations at (1X, ½X and ¼X) recommended rate caused a high average reduction percentage compared with the conventional formulation (1X) which was (87.66, 81.11 and 60.88%) respectively. The maximum average reduction percentages of the population of *A. nerii* were significant with nano (1X), (½ X) and (¼ X) compared with the conventional (1x) formulations (Table 5). Zhao *et al*. (2018) reported that nanoparticles have good promise regarding their treatment in nano-pesticide formulation owing to their covered big surface area, small size, and target modified properties. They reported that nano-based formulation could bring beneficial improvements in behaviors of pesticides and properties, such as dispersion, stability, solubility, targeting delivery and mobility. In addition, it might significantly enhance the safety, efficacy, and economic effects of traditional insecticides by improving and increasing the extending effect duration and efficiency, reducing the concentration required, providing the capability to control the release of active ingredients, and enhancing the stability of payloads from the environment, subsequently diminishing runoff and environmental residuals. This proves to be an environmentally friendly approach that helps in improving the efficacy and sustainability of agriculture with less input compared to traditional approaches (Servin *et al*., 2015).

Conclusion

To sum up, the foliar application of nanoformulations at recommended doses of neonicotinoid insecticides, acetamiprid, dinotefuran and thiamethoxam recorded a significant reduction compared with their traditional formulations in the Oleander scale insect population at 1, 7, 15 and 21 days after treatment on different olive varieties. Also, the nanoformulations at (1X, ½X and ¼X) recommended rates caused a high average reduction percentage compared with the conventional formulation (1X). However, the residual effects and efficacy of these nano-formulations continued up to twenty days after application against *A. nerii*. Results of this study might be highly recommended using nano-formulation of neonicotinoid insecticides in integrated pest management of olive scale insect pests' programs with caution about the probability of side effects of this formulation on the environmental components.

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