Egypt. J. Plant Prot. Res. Inst. (2021), 4 (4): 531 –544

Egyptian Journal of Plant Protection Research Institute

www.ejppri.eg.net

Application timing and efficacy of some insecticides against the grapevine mealybug *Planococcus ficus* (Hemiptera: Pseudococcidae) infested grapes in Egypt

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ARTICLE INFO

Article History

Received: 15 /10 / 2021

Accepted: 16/ 12 /2021

Keywords

Grapevine, mealybugs, *Planococcus ficus*, insecticides, mineral oils and buprofezin.

Abstract:

Mealybugs are the most important pests of cultivated crops in Egypt. Their damage on vineyards has dramatically increased during the past two decades. The grapevine mealybug, *Planococcus ficus* (Signoret) (Hemiptera: Pseudococcidae) is a primary pest of vineyards in Egypt. In this study, the effect of eight insecticides was evaluated against nymphs and adults of grapevine *P. ficus* during sunset and sunrise applications in 2019 and 2020 in Egypt. During the 2019 season, four weeks, the highest efficacy against the nymph mealybugs was achieved by the used mineral oil (Kz oil) and buprofezin with a 92% and 90% population reduction, respectively. The best effects after the sunset application were achieved with Kz oil and buprofezin after four weeks (95% and 92%).The results obtained from 2020 confirmed that during the sunrise application, the highest reductions in the adult populations were achieved by mineral oils (96%) and buprofezin (93.2%) after four weeks. Four weeks after the sunset application, the mineral oil had the highest effective against the adult mealybugs (92%) followed by spirotetramat (89%). In contrast, *Verticillium lecanii* showed the least effective against the adults, four weeks after the sunset application of 73%. The results provide an appropriate framework for insecticides, application and timing of control process against vineyard mealybug infestations in Egypt.

Introduction

Grapes in the world are one of the favorite fruits and have become one of the biggest fruits in production in 2019 the total production of grapes all over the world was around 77 million tons with a harvested area of 6.9 million hectares according to FAOSTAT (2019). Table grapes are one of the most important fruits produced in Egypt, second only to citrus in terms of production quantities. Grape cultivation is spread geographically from Alexandria in the north to Aswan in the south, which – combined with the production of early and late ripening grapes – enables the prolonged availability of fresh table grapes in the market from May to November. In 2020, commercial table grape production in Egypt is forecast to reach 1.42 million tons with a harvested area of 77895 hectares, while exports are estimated to reach 170,000 tons in 2020. The European Union remains the major importer of Egyptian table grapes. In Egypt, most of the grape area has been occupied by two main cultivars; *Thompson seedless* and *Romi Ahmar* as well as a small area cultivated with some local cultivars. After 1981 some new table grape cultivars were introduced and planted in different growing regions, both in Delta and desert areas. These cultivars were found to be different in their morphological characteristics and fruit quality.

Scale insects (Hemiptera: Coccoidea) are among the most important pests of cultivated crops worldwide (Mansour *et al*., 2017; Daane *et al*., 2012; Franco *et al*., 2009 and Sforza *et al*., 2005). Within this large group of insects, mealybugs (Pseudococcidae) constitute the second most species-rich family following the armored scales (Diaspididae) with more than 2000 described species to date (García *et al*., 2016). Twelve scale insects are found in Egypt. Mealybugs are small, soft-bodied insects, usually covered with a white mealy wax, which feeds on plant phloem and excrete honeydew (Williams and Watson, 1988). Most of the species are polyphagous infesting foliage, stems, or fruits. Their main damage is caused by ingestion of plant sap leading to plant vigor reduction, dropped the leaves, spottily yellowing, deformation of the shoot and twig, development of blisters like galls, loss of fruits, decreasing the normal tree physiological activities (Hassan *et al*., 2012). The vine mealybug, *Planococcus ficus* Signoret (Hemiptera: Pseudococcidae) is the key economic scale insect occurring in vineyards worldwide, including the Mediterranean basin, which represents its native range (Mansour *et al*., 2017; Franco *et al*., 2009; da Silva *et al*., 2014; Gülec *et al*., 2007; Reineke and Thiéry, 2016 and Walton *et al*., 2009).

Historically, using pesticides is the main controlling method for mealybugs including potassium cyanide, sodium cyanide, and sulfur fumigation (Essig, 1914) permitting the chlorinated hydrocarbons and organophosphates used at 1940s to the 1990s interval (Charles, 1985 and Frick, 1952). These chemicals were effective at low rates as 48 gm active ingredient/ha of ethyl parathion provided
Pseudococcus maritimus (Ehrhorn)
(Hemiptera: Pseudococcidae) control (Frick, 1952). Eventually, however, most of these pesticides became less effective (Flaherty *et al*., 1982) or ultimately banned from use because of concerns about non-target biota. Many organophosphates are still effectively using (Walton *et al*., 2009 and Sazo *et al*., 2008).

New chemicals with more novel modes of action have also been gaining in popularity, including neo-nicotinoids, insect growth regulators, botanicals, and biosynthesis inhibitors (Daane *et al*., 2006; Lo and Walker, 2010 and Sunitha *et al*., 2009). Many of these compounds are controversial due to significantly sub-lethal effects on non-target organisms (Henry *et al*., 2012). A major difference between the older and newer pesticides is the importance of coverage of the mealybug population, especially under the bark and for some species on the vine roots. Many of the older foliar sprays did not effectively contact and kill mealybugs in these more protected locations. Some of the newer pesticides have systemic properties and can be applied either through the irrigation system or as a foliar spray. For organic or sustainable farming programs, neem, light mineral oils, lime-sulfur, citrus products, and fatty acid soaps have been used. Few studies of these products have provided mixed results (Srinivas *et al*., 2007).

Therefore, in the present study, we evaluated eight insecticides with different modes of action against the grapevine mealybug *P. ficus* and determine the effect of all treatments after sunset and sunrise application to stand at the optimal time for their treatment applications to achieve the highest population reductions of mealybugs.

Materials and methods

1. Experimental design:

Field experiments were carried out to evaluate the efficacy of certain treatments against the grapevine mealybug, *P. ficus* on grapes grown at El-Noubaria, El-Beheira Governorate, Egypt in 2019 and 2020. Eight commercial formulated insecticides (Table 1) were used based on the Egyptian Ministry of Agriculture recommends for each insecticide to control sucking insects under field conditions.

The trial was laid out in a randomized complete block design in three replicates and control was concurrently conducted. For each replicate (3 trees) a spray was applied with a CP_3 knapsack sprayer (Cooper Pegler Co. Ltd., Northumberland, England). As soon as these steps were carried out, the insecticides were applied at the used rates (Table 1). Insecticides were sprayed in the early morning (A sunrise application) and repeated before the night (Sunset application) in anther treatments, the environmental conditions minimize the potential risk of spray drift and evaporation. The numbers of live mealybugs under the bark were counted on all trees in the plot before spraying and 1, 2, 3, and 4 weeks after application and the percentage population reduction in nymphs and adults separately was calculated (Henderson and Tilton, 1955) according to this 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

Table (1): The tested insecticides; shown as their basic information.

Common name	Trade name	Chemical classes	Formulation	Basic manufacture	Applic at-ion rate	Target pest
Sulfoxaflor	Closer	Sulfoximines	240 SC	Dow Agro Scienes, LLC, Indianapolis, IN	100 mL/ Fed.	Aphid, Whitefly, Leafhopper, Mite, Mealybugs
Abamectin + Thiamethoxam	Agri-flex	Avermectins + neonicotinoids	18.56% SC	Syngenta Crop Protection, LLC, Greensboro, NC	240 mL/ Fed.	Tomato leaf miner, Red spider mite, Aphid, Armored scale, Psyllid
Spirotetramat	Movento	Tetramic acid derivative (Ketoenole)	10% SC	Bayer Crop Science LP, Research TrianglePark, NC	75 mL/ 100 L	Aphid, Red spider mite, Whitefly, Some scales, Mealybugs
Thiamethoxam	Actara	Neonicotinoids	25% WG	Syngenta Crop Protection, LLC, Greensboro, NC	25 g/ 100 L	Aphid, Termite, Boll worm, Redpalm weevil, Leaf miner, Thrips, Leaf hoppers
Imidacloprid	Best	Neonicotinoids	25% WP	Bayer Crop Science LP, Research TrianglePark, NC	75 g/ 100 L	Aphid, Whitefly, Some scales, Mealybugs, Red spider mite, Fruit fly, Root-knot nematode, Thrips.
Buprofezin	Applaud	Buprofezin	25% SC	Dow AgroSciences, LLC, Indianapolis, IN	600 mL/ Fed.	Fruit fly, Mealybug, Whitefly, Thrips, Aphid, Leaf hoppers.
Verticillium lecanii	Bio-catch	Fungal agent	WP(1x108 CFU's/gm)	T. Stanes Company limited	3 L./ha	Whiteflies, Aphids, Thrips, Mealy bugs
Mineral oils	Kz oils	Mineral oil	95 %	KafrEl-Zayat Pesticides and Chemicals Co.	1.5L/ 100 L	Aphid, Red spider mite, Whitefly, Some scales, Mealybugs

2. Statistical analysis:

The plot system was designed in a randomized complete block design (RCBD) with eight treatments compared to control and three replicates were used. The analysis was performed using the Costat program, version 6.311 (CoHort Software, Monterey, CA, USA) at a 0.05 probability level.

Results and discussion

The present study investigated the impact of insecticides applied as a foliar treatment against the nymph and adult of Grapevine mealybug, *P. ficus* Signoret during 2019 and 2020 seasons. In the past decade, the economic losses resulting from vineyard mealybug infestations have increased (Rajagopal *et al*., 1997).

Mealybugs are phloem, vine's roots, trunk, canes, leaves, and fruit clusters sucking out plant fluids. Population size depends on the number of annual generations, female fecundity, preferred feeding locations, and temperature tolerances (Charles, 1982). Mealybugs accumulate on the lower surface of leaves and in the grape clusters, especially in late summer and early fall, where they select their favorite place to feed on the plant juice and secrete honeydew.

Due to this accumulation of mealybugs, the black sooty mold fungus develops on the honeydew excretions (Charles, 1982). For table grape growers, any live or dead mealybugs and the honeydew or sooty molds will cause cosmetic damage to the grape cluster and reduce its marketability (Tsai *et al*., 2011). We undertook this study to develop suitable management programs to suppress the pest population below the critical economic limit that affect the yield of the vineyard.

1. Efficacy on the grapevine mealybug in 2019:

The grapevine mealybug, *P. ficus* was affected differently with the tested insecticides. Significant differences were found between the insecticides in their effects against the populations of nymphs during the sunrise application (Tables 2 and 3). After one week, these tests revealed that the most striking reduction in the populations of nymphs was achieved by Kz oil as a mineral oil (75.64%) followed by buprofezin (70.70%), abamectin+thiamethoxam (70.13%), spirotetramat (69.91%), thiamethoxam (68.25%), sulfoxaflor (68.23%), imidacloprid (65.26%) and *V. lecanii* (26.23%), respectively.

After four weeks, the used mineral oil (Kz oil) and buprofezin achieved the highest mean reduction percentages of the treated population exhibiting 92.09% and 991.58% reduction, respectively. The least effective insecticide against the nymphs was *V. lecanii* as it caused 58.98% reduction in the treated population. During the sunset application, the highest population reduction of the nymphs after four weeks was achieved by the used mineral oil (Kz oil), which caused 95.44% reduction in the treated nymph population.

For adult populations, the used mineral oil showed a lower effect when applied after the sunrise than that obtained when applied after the sunset (Tables 4 and 5), suggesting that sunset is the optimal time for controlling the mealy bug adults by its foliar application. In case of the application after the sunrise, the used mineral oil achieved the highest population reduction after four weeks (89.88%) among all the other treatments.

Similarly, after the sunset application the adult population was highly reduced when treated with the used mineral oil and spirotetramat as they exhibited a reduction percent of 92.46% and 89.25%, respectively (Table 5). The least effective treatments during the sunset application were *V.*

lecanii with 57.02% reduction and imidacloprid with 69.98% reduction, respectively in the treated adult population. The adult population reduction effects after the sunset application were achieved differently according to the tested insecticide as they were arranged in desending order as the following: the used mineral oil (Kz oil), spirotetramat, abamectin+thiamethoxam, sulfoxaflor, buprofezin thiamethoxam, imidacloprid and *V. lecanii* as they respectively reduced the treated population with 84.51%, 82.18%, 81.61%, 79.78%, 77.55%, 73.89%, 69.98% and 57.02% reduction in the same array (Table **5**).

2. Efficacy on the grapevine mealybug in 2020:

The insecticidal activity results obtained in 2020 against the grapevine mealybug were highly similar to our 2019 findings. The data confirm that the time of application has a significant effect on the reduction of the treated mealybugs population already one-week after application.

After the sunset application, the reduction percent of the treated nymph population was differed according to the applied insecticide. The highest reduction percentage was achieved by the used mineral oil (Kz oil) as it caused 87.37% average reduction percent of the treated population and abamectin+thiamethoxam with 85.76% average population reduction of the treated nymphs. Sulfoxaflor, spirotetramat and buprofezin were near to the mixture of abamectin+thiamethoxam in their effect with non-significant difference as they exhibited 83.77%, 84.69% and 82.36% reduction of the treated population, respectively. While imidacloprid and *V. lecanii* were less effective with 76.14 and 60.43% reduction percent, respectively.

During the sunrise application, it was found that after one week, the reduction in nymphs population was distributed as the used mineral oil was the highest effective with 75.99% reduction, followed by abamectin+thiamethoxam with 73.55% reduction, spirotetramat (72.76%), sulfoxaflor (71.93%), thiamethoxam (70.68%), buprofezin (69.79%), imidacloprid (66.44%) and *V. lecanii* (64.82%) in descending order of activity (Tables 6 and 7).

After two weeks of application, the highest reduction during the sunrise application was achieved by abamectin+thiamethoxam (86.12%) and sulfoxaflor (85.32%) with non-significance between them. The residual effects among the tested insecticides four weeks after the application were the highest in case of the used mineral oil (Kz oil) with 99.08% reduction in the treated nymphs population. This effect was changed according to the tested insecticide as the obtained reduction in the treated nymph population was 96.83%, 94.89%, 93.91%, 91.51%, 92.23%, 78.66% and 66.06% by buprofezin, thiamethoxam, abamectin+thiamethoxam, sulfoxaflor, spirotetramat, imidacloprid and *V. lecanii* in the same arrangement (Tables 6 and 7).

Against the adult females, one week after the sunset application, the highest reduction effect (73.57%) and (71.74%) with non-significance difference between them were due to application of the mineral oil (Kz oil) and the abamectin+thiamethoxam mixture, respectively (Tables 8 and 9). In contrast, the lowest reductions in the adult population were 24.22% and 59.12% are obtained by treatment with *V. lecanii* and imidacloprid insecticides, respectively after one week of sunrise application.

Four weeks after the sunset application, our results showed that the highest effects were achieved by the used mineral oil (92.46%) and spirotetramat (89.25%) with non significance between them, whereas the least effective insecticide against the adults was *V. lecanii* with 73.02% reduction and imidacloprid with 73.28% reduction in the treated adult population.

From the obtained findings, the results confirm the usefulness of insecticides as a tool to reduce grapevine mealybug nymphs and adults. The data furthermore confirms that the highest reduction against adults was found after four weeks by mineral oil for both the sunrise and sunset application, while *V. lecanii* proved to be the least effective. Overall, we found that the sunset application of the used insecticides was better than the sunrise application for controlling the *P. ficus* population.

This phenomenon is more likely referred to a more effective mode of action of these insecticides during this period on the insects due to the climatic conditions or insect foraging behavior or activity, which makes them more susceptible to the insecticides (Piechowicz and Grodzicki, 2014).

The obtained results agreed with other studies, which found that mineral oils are the most important insecticides for controlling the mealybugs as it blocks the spiracles and trachea through which insects breathe (Helmy *et al.*, 2012). The mineral oil reduced populations of the soft scale insect *Pulvinaria psidii* Maskell (Hemiptera: Coccidae) infesting guava trees by more than 90% after 60 days of treatment (Helmy *et al.*, 2012).

The mineral oils were effective, economically safe, and the pests did not get developing resistance to them (Aly *et al*., 1984). Similarly, Helmy *et al.*(2012) found that the recommended spray gave satisfactory control of *Leucaspis riccae* Targ (Hemiptera : Diaspididae) and had a moderate effect on *Euphyllura straminea* Loginova (Hemiptera: Aphalaridae), whereas super misrona (1.5%) had a superior effect (93%) and (88%), respectively, followed by Kz oil and super royal oil.

El-Sahn *et al*. (2007) reported that the mayonnaise oil (Alboleum) achieved the highest population reduction against *Saissetia coffeae* (Walker) (Hemiptera: Coccidae) infesting *Cycas revolute* Thunb (Cycadaceae) till 25 days after spraying. Orange, sesame and jasmine oils were tested against two species of mealybugs, *Icerya seychellarum* (Wes twood) (Hemiptera: Monophelibidae) and *Ferrisia virgata* Cockerell (Hemiptera: Pseudococcidae) in guava trees with different concentration, the author found that after application the adults decreased in numbers, also nymphs were recorded as more sensitive than adults (Mohamed and Bakry, 2019).

Synergistic effects have also been investigated with a combination of spirotetramate (12%) + imidacloprid (36 %) 480 SC, spirotetramate 150 OD, imidacloprid 200 SL, thiodicarb 75 WP and profenophos 50 EC tested against the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on Bt cotton during 2007 and 2008 and the results indicated that application of spirotetramate (12%) + imidacloprid (36 %) 480 SC @ 625 ml/ ha was the most effective in control all mealybug tested (El-Sahn *et al*., 2007).

In contrary study, buprofezin was found to be the most effective insecticide for the control of mealybug on cotton with more than 95% reduction in the pest population 3 days after spraying followed by carbaryl and chloropyriphos (Mohamed and Bakry, 2019).

Laboratory studies on the effect of pesticides against mealybugs give similar results to our field experiment results. The diafenthiuron, imidacloprid, carbosulfan, methamidophos, acetamiprid and thiamethoxams found to be extremely toxic to *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) larvae with over 90% mortality after 48 hrs of applying. No successful pupation was recorded after treatment with acetamiprid, whereas successful pupation rate was highest in the buprofezin treated larvae (72%) (Nasreen *et al*., 2007).

The toxicity of imidacloprid and diafenthiuron to eggs, larvae and adults of *C. carnea* were investigated under laboratory conditions while, the imidacloprid at 0.28 ml/l recommended dose recorded 15% egg mortality and larval mortality by 27% and 33 % after ingestion and contact, respectively, and 50% adult mortality. Whereas, the egg mortality was about 15.38 %, larval mortality of 23.33 % and adult mortality of 26.67% was caused by diafenthiuron (Preetha *et al*., 2009).

Our work has led us to conclude that the time of application of insecticides has a significant impact on the effective control of the grapevine mealybug, *P. ficus* and the sunset application give the best overall results. The results of this study found that the time of application with a range of different insecticides, applied as foliar treatments, reduced the nymphs and adults of grapevine mealybug, *P. ficus* during the two seasons of 2019 and 2020. We have devised a strategy which increased the effect of insecticides against *P. ficus*. The sunset application provides a powerful tool for controlling the nymph of the mealybug, *P. ficus*. In addition, the evidence from this study suggests significant differences between all insecticides against *P. ficus* with the most effective being mineral oils four weeks after application.

These different effects may be due to the different mode of action of the tested insecticides as sulfoxaflor (Closer) is nicotinic acetylcholine receptor (nAChR) agonist (Henry *et al*., 2012), abamectin + thiamethoxam (Agri-flex) affect as GABA and glutamate-gated chloride channel (GluCl) allosteric modulators, nicotinic acetylcholine receptor (nAChR) agonist (Srinivas *et al*., 2007), while spirotetramat (Movento) works as lipid biosynthesis inhibitor (Growth inhibitor) (Ben-Dov, 1994), imidacloprid (Best) nicotinic acetylcholine receptor (nAChR) agonist (Henderson and Tilton, 1955), buprofezin (Applaud) chitin synthesis disruptor, the *V. lecanii* (Bio-catch) spore of the fungus, when it comes in contact with the cuticle (Skin) of the target pest insect, germinates and grows directly through the spiracle in the cuticle into the inner body of the host, whenever, mineral oils (Kz oils) It makes a thin film around the insect that prevents it from breathing and its ability to excrete waste.

Table (2): Effect of different foliar applied insecticides on the nymph population of grapevine mealybug, *Planococcus ficus* in 2019; shown as mean numbers.

Time of application	Interval (week)	Mean nymphal population numbers/3 plants after different periods of spray									
		Control	Sulfoxaflor	Abamectin +Thiamethoxam	Spirotetramat	Thiamethoxam	Imidacloprid	Buprofezin	*V. lecanii*	Kz oil	Mean no. of interval days
Sunrise	1	118 b	37.33 gh	32.33 h-k	33.33 g-j	34.66 ghi	39.33 g	34 g-j	79.66 c	27.33 jk	48.44 a
	2	121.33 ab	18.33 mno	17.66 m-p	20.33 lmn	26.0 kl	30.33 ijk	26.33 kl	66 d	17.33 m-p	38.18 b
	3	120.33 ab	11.66 opq	10.33 pq	15.33 m-q	17.0 m-p	27.33 jk	15.66 m-q	58.0e	12 opq	31.96c
	4	124.33 a	13.66 m-q	13 m-q	17.66 m-p	20.66 lm	30.33 ijk	12.66 n-q	46.66 f	9.33 q	32.03 c
	Average	**121 a**	**20.25 ef**	**18.33 fg**	**21.66 e**	**24.58 d**	**31.83 c**	**22.16 e**	**62.58 b**	**16.5 g**	
Sunset	1	117.66 a	31.66 fg	27.66 gh	32.33 fg	36.33 ef	37.66 de	31.66 fg	61 b	27 gh	44.77 a
	2	116 a	15.33 kl	12 klm	12.33 klm	20.66 ij	24.33 hi	21 ij	52.66 c	14 klm	32.03 b
	3	115.66 a	11.33 k-n	7.33mn	11.33 k-n	13.66 klm	16.66 jk	10.66 k-n	41.33 d	8.66 lmn	26.29 c
	4	118 a	12.66 klm	10 k-n	9.33 lmn	13.66 klm	21.33 ij	8.66 lmn	28 gh	5 n	25.18 c
	Average	**116.83 a**	**17.75 e**	**14.25 f**	**16.33 e**	**21.08 d**	**25 c**	**18 e**	**45.75 b**	**13.66 f**	

Average. general mean number of insects; Sulfoxa., Sulfoxaflor; Abamec., Abamectin; Thiameth., Thiamethoxam; Spirot., Spirotetramat; Imidac., Imidacloprid; Buprof., Buprofezin; *V. lecanii, Verticillium lecanii*; Mean, Mean no. of interval days. Means followed with the same letter (s) are not significantly different from each other at P= 0.05

Table (3): Effect of different foliar applied insecticides on the nymph population of grapevine mealy-bug, *Planococcus ficus* in 2019; shown as reduction%.

Time of application	Mean population of the reduction percentage of nymphal stage after different period of spray[†]									Mean no. of interval days
	Interval (week)	Sulfoxaflor	Abamectin +Thiamethoxam	Spirotetramat	Thiamethoxam	Imidacloprid	Buprofezin	*V. lecanii*	Kz oil	
Sunrise	1	68.23 hi	70.13 ghi	69.91 ghi	68.25 hi	65.26 i	70.70 f-i	26.32 m	75.64 e-h	64.31 c
	2	84.84 a-d	84.48 a-d	82.18 b-e	77.40 d-g	73.99 fgh	77.93 def	40.61 l	84.94 a-d	75.80 b
	3	90.29 abc	90.68 ab	86.43 abc	84.81a-d	76.29 efg	86.75 abc	47.35 k	89.55 abc	81.52 a
	4	88.98 abc	88.68 abc	84.87a-d	82.05 cde	74.59 fgh	89.65 abc	58.98 j	92.09 a	82.49 a
	Average	**83.08 ab**	**83.50 ab**	**80.85 b**	**78.13c**	**72.54 d**	**81.26 b**	**43.31 e**	**85.56 a**	
Sunset	1	71.18 f-i	72.49 f-i	69.79 g-j	67.81 ij	64.20 j	69.13 hij	47.70 l	75.13 e-h	67.18 c
	2	85.93 bc	87.79 abc	88.39abc	80.40 de	76.68 ef	79.32 de	54.12 k	87.02 bc	79.96 b
	3	89.43 abc	92.68 ab	89.25abc	87.76 abc	83.88 cd	89.43 abc	63.90 j	91.91 ab	86.03 a
	4	88.54 abc	90.07 abc	91.36 abc	87.88 abc	79.80 de	91.58 abc	75.98 efg	95.44 a	87.58 a
	Average	**83.77 bc**	**85.76 ab**	**84.69 abc**	**80.97 d**	**76.14 e**	**82.36 cd**	**60.43 f**	**87.37 a**	

Means followed with the same letter (s) are not significantly different from each other at P= 0.05. The percentage of the reduction after different periods of spraying.

Table (4): Effect of different foliar applied insecticides on the adult population of grapevine mealybug, *Planococcus ficus* in 2019; shown as mean numbers.

Time of application	Interval (week)	Mean population of adult stage /3 plants after different periods of spray									Mean no. of interval days
		Control	Sulfoxaflor	Abamectin +Thiamethoxam	Spirotetramat	Thiamethoxam	Imidacloprid	Buprofezin	*V. lecanii*	Kz oil	
Sunrise	1	53.33 a	16.33 f-i	16.33 f-i	16 f-j	18.66 efg	22.66 e	20.33 efg	38.33 b	15 g-j	24.11 a
	2	55 a	8.66 lm	9 klm	10.66 i-m	14.66 g-k	20.66 ef	15.33 f-j	33.33 c	9.33 klm	19.62 b
	3	56 a	7.33 lm	6.66 lm	9 klm	11.33 h-m	14.66 g-k	10.33 j-m	29.66 d	7.66 lm	16.96 c
	4	53.3 a	8.33 lm	8.33 lm	10.33 j-m	11.66 h-l	16.66 fgh	7.66 lm	23.33 e	5.33 m	16.11 c
	Average	**54.41 a**	**10.16 e**	**10.08 e**	**11.5 e**	**14.08 d**	**18.66 c**	**13.41 d**	**31.16 b**	**9.33 e**	
Sunset	1	55.66 a	16 ef	15.66 ef	16 ef	17.66 de	21.33 cd	17.33 de	28.33 b	14.66 efg	22.51 a
	2	55 a	9.66 g-j	9.66 g-j	7.33 ijk	14.33 e-h	17.33 de	11.33 f-i	26.66 b	10 g-j	17.92 b
	3	58 a	7.66 ijk	7 ijk	7 ijk	11 f-i	14 e-h	9.33 h-k	21.66 c	5.66 jk	15.70 c
	4	57.66 a	9.33 h-k	8.66 ijk	8.66 ijk	11.33 f-i	15.33 ef	10 g-j	14.66 efg	4.33 k	15.55 c
	Average	**56.58 a**	**10.66 ef**	**10.25 ef**	**9.75 f**	**13.58 d**	**22.83 b**	**12 e**	**22.83 b**	**8.66 f**	

Means followed with the same letter (s) are not significantly different from each other at P= 0.05.

Table (5): Effect of different foliar applied insecticides on the adult population of grapevine mealybug, *Planococcus ficus* Signoret in 2019; shown as reduction%.

Time of application	Mean population of the reduction percentage of nymphal stage after different period of spray									Mean no. of interval days
	Interval (week)	Sulfoxaflor	Abamectin +Thiamethoxam	Spirotetramat	Thiamethoxam	Imidacloprid	Buprofezin	*V. lecanii*	Kz oils	
Sunrise	1	67.40 cd	69.42 cd	67.77 cd	64.42 de	55.64 ef	62.61 de	22.18 i	71.59 bcd	60.13 c
	2	83.38 ab	83.85 ab	79.11 abc	72.74 bcd	60.81 def	72.75 bcd	34.44 h	82.42 ab	71.19 b
	3	86.10 a	88.25 a	82.78 ab	79.16 abc	72.38 bcd	81.85 ab	42.48 g	85.80 a	77.35 a
	4	83.47 ab	84.47 ab	79.19 abc	77.87 abc	67.31 cd	85.91 a	52.59 f	89.88 a	77.59 a
	Average	**80.09 abc**	**81.50 ab**	**77.21 bcd**	**73.55 d**	**64.04 e**	**75.78 cd**	**37.92 f**	**82.42 a**	
Sunset	1	69.35 i-l	71.74 h-k	68.07 jkl	65.60 kl	61.96 l	67.15 jkl	45.91 m	73.57 f-k	65.42 c
	2	81.29 b-g	82.31 b-g	85.01 a-e	71.69 h-k	68.74 jkl	78.14 d-i	48.62 m	81.78 b-g	74.70 b
	3	85.75 a-e	87.81 a-d	86.37 a-d	79.56 d-h	75.94 e-j	83.08 b-f	60.54 l	90.26 ab	81.16 a
	4	82.72 b-g	84.59 a-e	89.25 abc	78.71d-i	73.28 f-k	81.85 b-g	73.02 g-k	92.46 a	81.98 a
	Average	**79.78 bc**	**81.61 ab**	**82.18 ab**	**73.89 d**	**69.98 e**	**77.55 c**	**57.02 f**	**84.51 a**	

Means followed with the same letter (s) are not significantly different from each other at P= 0.05.

Table (6): Effect of different foliar applied insecticides on the nymph population of grapevine mealybug, *Planococcus ficus* in 2020; shown as mean numbers.

Time of application	Interval (week)	Mean population of nymph stage/3 plants after different periods of spray									Mean no. of interval days
		Control	Sulfoxaflor	Abamectin +Thiamethoxam	Spirotetramat	Thiamethoxam	Imidacloprid	Buprofezin	*V. lecanii*	Mineral oils	
Sunrise	1	66.66 b	17 gh	17 gh	17 gh	17 gh	20 fg	20 fg	43 c	16 gh	25.96 a
	2	67.33 b	9 j-m	9 j-m	9.66 jkl	11.33 ijk	14.33 hi	13.66 hi	38 d	9.66 jkl	20.22 b
	3	72 a	5.33 l-o	4.66 m-p	6.33 l-o	7.66 k-n	13 hij	7 lmn	31 e	4.33 nop	16.81 c
	4	73.33 a	5.66 l-o	4.33 nop	5.33 l-o	3.33 nop	14 hi	2.33 op	22 f	0.66 p	14.55 d
	Average	**69.83 a**	**9.25 def**	**8.75 ef**	**9.58 de**	**9.83 de**	**15.33 c**	**10.75 d**	**33.5 b**	**7.66 f**	
Sunset	1	87.33 b	22.66 ghi	20 ij	24.33 fg	23.66 fgh	26.66 f	24.33 fg	42 c	20.66 hij	32.40 a
	2	87.33 b	10.66 no	9 opq	8.66 o-r	14.66 lm	18.33 jk	13.33 mn	35 d	10 op	23 b
	3	89.66 b	6.66 p-s	5 rs	8 o-s	8.66 o-r	13 mn	6.33 p-s	31.33 e	4.66 s	19.25 c
	4	92 a	6.66 p-s	5.66 qrs	6.66 p-s	9.66 op	16.66 kl	5.33 qrs	22.66 ghi	2.0 t	18.59 c
	Average	**89.08 a**	**11.66 e**	**9.91 f**	**11.91 e**	**14.16 d**	**18.66 c**	**12.33 e**	**32.75 b**	**9.33 f**	

Means followed with the same letter (s) are not significantly different from each other at P= 0.05.

Table (7): Effect of different foliar applied insecticides on the nymph population of grapevine mealy-bug, *Planococcus ficus* Signoret in 2020; shown as reduction%.

Time of application	Mean population of the reduction percentage of nymphal stage after different period of spray									Mean no. of interval days
	Interval (week)	Sulfoxaflor	Abamectin +Thiamethoxam	Spirotetramat	Thiamethoxam	Imidacloprid	Buprofezin	*V. lecanii*	Kz oil	
Sunrise	1	71.93 lm	73.55 jkl	72.76 kl	70.68 lmn	66.44 mn	69.79 lmn	64.82 n	75.99 i-l	70.75 d
	2	85.32 d-g	86.12 d-g	84.60 e-h	81.64 f-i	76.05 ijkl	79.61 g-j	36.62 p	85.60 d-g	76.95 c
	3	91.88 bcd	93.30 abc	90.52 b-e	87.83 c-f	79.67 g-j	90.25 b-e	51.60 o	93.99 abc	84.88 b
	4	91.51 b-e	93.91 abc	92.23 bcd	94.89 abc	78.66 h-k	96.83 ab	66.06 mn	99.08 a	89.15 a
	Average	**85.16 b**	**86.72 ab**	**85.03 b**	**83.76 b**	**75.20 c**	**84.12 b**	**54.78 d**	**88.67 a**	
Sunset	1	71.18 f-i	72.49 f-i	69.79 g-j	67.81 ij	64.20 j	69.13 hij	47.70 l	75.13 e-h	67.18 c
	2	85.93 bc	87.79 abc	88.39 abc	80.40 de	76.68 ef	79.32 de	54.12 k	87.02 bc	79.96 b
	3	89.43 abc	92.68 ab	89.25 abc	87.76 abc	83.88 cd	89.43 abc	63.90 j	91.91 ab	86.03 a
	4	88.54 abc	90.07 abc	91.36 abc	87.88 abc	79.80 de	91.58 abc	75.98 efg	95.44 a	87.58 a
	Average	**83.77 bc**	**85.76 ab**	**84.69 abc**	**80.97 d**	**76.14 e**	**82.36 cd**	**60.43 f**	**87.37 a**	

Means followed with the same letter (s) are not significantly different from each other at P= 0.05.

Table (8): Effect of different foliar applied insecticides on the adult population of grapevine mealybug, *Planococcus ficus* in 2020; shown as mean numbers.

Time of application	Interval (week)	Mean population of adult stage/3 plants after different periods of spray									Mean no. of interval days
		Control	Sulfoxaflor	Abamectin+ Thiamethoxam	Spirotetramat	Thiamethoxam	Imidacloprid	Buprofezin	*V. lecanii*	Kz oil	
Sunrise	1	28.66 b	8.66 fgh	7.33 f-i	7 g-j	9 fg	10 ef	10 ef	18 c	7.33 f-i	11.77 a
	2	28.66 b	4.33 j-n	3.66 k-n	4 k-n	7.66 fgh	9 fg	6.33 g-k	13.66 d	4.66 i-m	9.11 b
	3	29 b	3.33 lmn	2.33 mn	3 lmn	6 h-l	6 h-l	4.33 j-n	12 de	3 lmn	7.66 c
	4	32.66 a	4 klm	3 lmn	3.66 k-n	3 lmn	8fgh	2.33 mn	10 ef	1.33 n	7.55 c
	Average	**29.75 a**	**5.08 ef**	**4.08 f**	**4.41 f**	**6.41 d**	**8.25 c**	**5.75 de**	**13.41 b**	**4.08 f**	
Sunset	1	40.33 b	11.33 gh	11 hi	11.66 gh	12.33 fgh	14.66 ef	14 efg	22 c	10 h-k	16.37 a
	2	40 b	5.66 l-p	5 m-p	4.33 nop	14.66 ef	11.66 gh	8 j-m	18.66 d	6.33 l-o	12.70 b
	3	41.66 ab	4.33 nop	3.66 op	4.33 nop	6.66 l-o	8.33 i-l	5.33 l-p	15.33 e	3.33 op	10.33 c
	4	43.33 a	5.33 l-p	4.33 nop	4.66 nop	7.66 k-n	10 h-k	4.66 nop	10.66 hij	2.33 p	10.33 c
	Average	**41.33 a**	**6.66 e**	**6 e**	**6.25 e**	**10.33 c**	**11.16 c**	**8 d**	**16.66 b**	**5.5 e**	

Means followed with the same letter (s) are not significantly different from each other at P= 0.05.

Table (9): Effect of different foliar applied insecticides on the adult population of grapevine mealybug, *Planococcus ficus* in 2020; shown as reduction%.

Time of application	Mean population of the reduction percentage of nymphal stage after different period of spray									
	Interval (week)	Sulfoxaflor	Abamectin +Thiamethoxam	Spirotetramat	Thiamethoxam	Imidacloprid	Buprofezin	*V. lecanii*	Kz oil	Mean no. of interval days
Sunrise	1	69.08 fgh	71.28 fgh	70.56 fgh	67.51 ghi	59.12 i	63.77 hi	24.22 l	73.09 fgh	62.33 d
	2	84.49 a-e	85.49 a-e	83.41 b-e	72.44 fgh	63.29 hi	77.08 defg	42.27 k	82.81 b-e	73.91 c
	3	88.24 abc	90.75 ab	87.69 a-d	78.71 c-f	75.81 efg	84.51 a-e	49.93 j	89.24 abc	80.61 b
	4	87.49 a-d	89.12 abc	85.77 a-e	90.61ab	71.36 fgh	92.62 ab	62.55 hi	95.81 a	84.42 a
	Average	**82.32 ab**	**84.16 a**	**81.86ab**	**77.32 c**	**67.40 d**	**79.50 bc**	**44.74 e**	**85.24 a**	
Sunset	1	69.35 i-l	71.74 h-k	68.073 jkl	65.60 kl	61.96 l	67.15 jkl	45.91 m	73.57 f-k	65.42 c
	2	81.29 b-g	82.31 b-g	85.01 a-e	71.69 h-k	68.74 jkl	78.14 d-i	48.62 m	81.78 b-g	74.70 b
	3	85.75 a-e	87.81 a-d	86.37 a-d	79.56 c-h	75.94 e-j	83.08 b-f	60.54 l	90.26 ab	81.16 a
	4	82.72 b-g	84.59 a-e	89.25 abc	78.71 d-i	73.28 f-k	81.85 b-g	73.02 g-k	92.46 a	81.98 a
	Average	**79.78 bc**	**81.61 ab**	**82.16 ab**	**73.89 d**	**69.98 e**	**77.55 c**	**57.02 f**	**84.51 a**	

Means followed with the same letter (s) are not significantly different from each other at P= 0.05.

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