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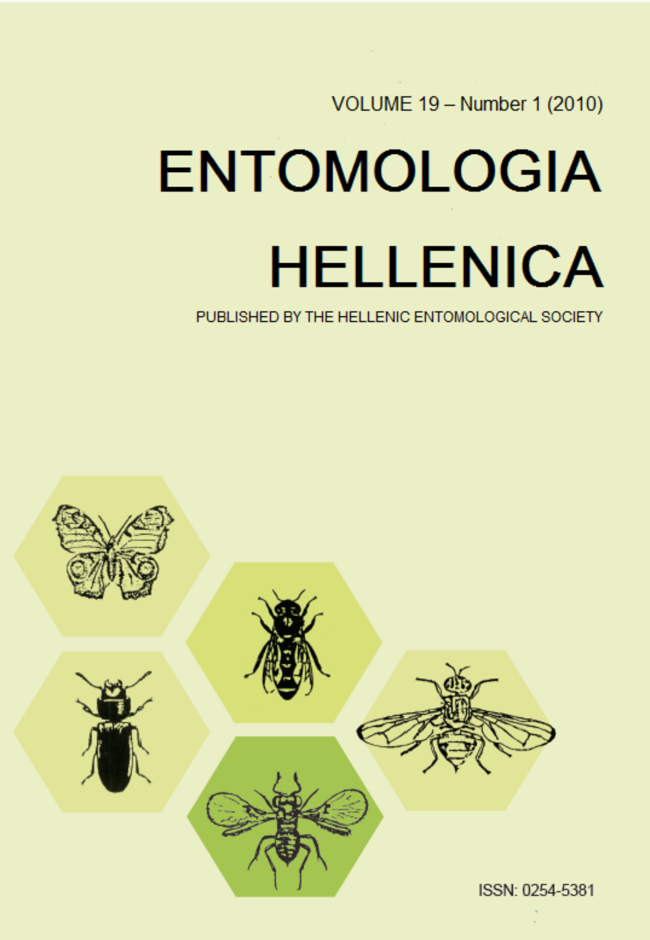

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Assessment of the performance of some new insecticides for the control of the vine mealybug *Planococcus ficus* in a Tunisian vineyard

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ABSTRACT

Mealybugs (Hemiptera: Pseudococcidae) cause major economic losses in many Tunisian grape-growing areas. In an attempt to improve management strategies for the Vine Mealybug (VM) *Planococcus ficus* (Signoret), three insecticides, imidacloprid, Prev-Am® and spirotetramat, were evaluated for their effect on this insect on vine, with reference to methidathion. The systemic insecticide spirotetramat (Movento® 150 OD) provided the greatest control performance of the VM populations, compared to the contact insecticide methidathion, the systemic insecticide imidacloprid applied through furrow irrigated system, and to Prev-Am®, a new contact biopesticide. Three weeks after treatment, VM eggs and adult females were missing from spirotetramat-treated vines. Additionally, spirotetramat supplied a long-residual activity against VM populations and prevented further spread of these insects on vine leaves. Therefore, this new systemic insecticide could be incorporated in an Integrated Pest Management program for VM control in Tunisian vineyards. Despite its short-residual activity, Prev-Am® was shown to be more effective than both methidathion and imidacloprid, mainly on VM eggs and L3 nymphs, and resulted in the highest level of VM L1-L2 nymph decrease on vine trunks. Hence, this biopesticide might prove useful for VM management in vineyards.

KEYWORDS: Tunisia, vine, *Planococcus ficus*, insecticide treatment, Integrated Pest Management.

Introduction

Mealybugs (Hemiptera: Pseudococidae) are small, soft-bodied noxious insect pests that feed by sucking plant sap. Among mealybug species, *Planococcus ficus* (Signoret), the vine mealybug is considered key pest of grapevine, causing serious damages on vine production and quality in many grape growing regions of the world (Ben-Dov 1994, Godinho and Franco 2001, Godfrey et al. 2003, Daane et al. 2004, De Borbon et al. 2004, Walton and Pringle 2004, Buonocore et al. 2008, Walton et al. 2009).

In Tunisia, two mealybug species have been identified in vineyards, the Vine Mealybug (VM) *P. ficus* and the Citrus Mealybug

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(CM) *P. citri* (Risso) (Mansour 2008, Mahfoudhi and Dhouibi 2009, Mansour et al. 2009). Very few studies have been performed on the management and the control of these insects in Tunisian vineyards.

Both species decrease crop quality by excreting honeydew, which promotes the development of sooty mold fungi and furthermore they are vectors of several viral diseases of grapevines, such as the leafroll associated virus 3 (GLRaV-3) (Cabaleiro and Segura 1997, De Borbon et al. 2004, Tsai et al. 2008, Mahfoudhi et al. 2009). In order to minimize crop losses and to constrain the serious problem of viral diseases in vineyards, vine producers are encouraged to use control measures against these pests.

A strategy for an effective control of mealybugs should be based on an integrated pest management program, involving monitoring of pest population by sex-pheromone traps and the integration of different control methods such as cultural practices, biological control, and insecticide applications.

Chemical treatments using synthetic insecticides are still the most widely used tools to cope with mealybug problems (Franco et al. 2009). Nevertheless, chemical products may be ineffective because mealybugs often reside beneath the vine's bark or underground (Daane et al. 2006), and due to the typical waxy body cover and the clumped spatial distribution pattern of these insects (Franco et al. 2009). Broad spectrum insecticides may also negatively impact the natural enemies of mealybugs (Walton and Pringle 1999). Furthermore, insecticide resistance has also caused the use of some chemicals to be unsustainable (Franco et al. 2009).

In Tunisian vineyards, the organophosphates methidathion and chlorpyriphos-ethyl, applied in spring-summer, are extensively used to control mealybugs, despite their limited effectiveness (Youssfi 2007). Therefore, the investigation of more selective and effective insecticides has been carried out in order to provide growers with better tools for mealybug pest management in vineyards.

In the present study, the assessment of the impact of three insecticides (spiro–tetramat, Prev-Am® and imidacloprid) on summer VM populations on vine was carried out and compared to the contact insecticide methidathion in an attempt to refine and strengthen management programs for mealybugs.

Materials and Methods

Study site

The experiment was conducted in summer 2008 in a table-grape vineyard, heavily infested by VM populations, located in Takelsa delegation (36°48'58"N, 10°38'48"E, 98 m a.s.l.).

The study site is a 1.5 ha 21-years old vineyard, planted with the "Muscat d'Italie" variety and furrow irrigated. The vineyard was installed according to pergola system and with a distance of plantation between vines of 4 x 2 m. During the present study, no insecticide intervention was performed in this vineyard.

Insecticide trial was conducted on "Muscat d'Italie" vines in a plot (195 vines) of Takelsa vineyard.

Treatments and rates

The aim of this insecticide trial was to evaluate the effectiveness of (a) Prev-Am® (200 ml/hl, ORO AGRI International LTD), a contact biopesticide containing orange oil, borax and organic surfactants, (b) imidacloprid (Confidor, 3 ml/l/vine, Bayer CropScience), a systemic nicotinoid insecticide, and (c) spirotetramat (Movento® 150 OD, 120 ml/hl, Bayer CropScience), a systemic tetramic acid insecticide, on the control of summer mealybug populations. (d) Methidathion (Medakill 40% EC, 150 ml/hl, Chimic Agri), a contact organophosphate insecticide commonly used to control mealybug populations in Tunisian vineyards, was selected as reference insecticide to be compared with the tested active ingredients. (e) An untreated control was also considered.

Timing of application and experimental design

The follow-up of the male flight activity of the VM was performed, in order to specify the appropriate moment for the treatment application, using two Delta traps (Scentry Biologicals INC., USA) baited with one pheromone lure (Biosystèmes France s.a.r.l.) each. Franco et al. (2009) suggested that monitoring systems using mealybug female sex-pheromone provide vital information for the timing of insecticide applications. Each pheromone-trap was hung in the vine canopy approximately 1.5 m above the ground. The traps were changed weekly and all VM adult males were counted using binocular microscope; while the lures were changed every three weeks.

Each insecticide treatment was applied on June 12 (T), precisely one day after the first summer VM male flight peak was noted, and when mealybug population consisted of mainly young instar nymphs, the most susceptible stages. Treatments were replicated 3 times in a randomized complete block design. Each replicate encompassed 13 vines.

Application equipment

All insecticides, except imidacloprid, were applied using an atomizer with a capacity of 12 L and an herbicide sprayer with a capacity of 18 L. To prepare the soil to receive imidacloprid, a 1-day pretreatment irrigation was carried out and imidacloprid was then applied into the furrows. To avoid the loss of this insecticide within the soil and to move it into the root zone, the treatment application was followed by a 1-day post-treatment irrigation.

Post-treatment evaluation procedure

Five vines were randomly selected per replicate for mealybug counts. A 5-minute time search was conducted on each single vine trunk (including cordon and canes), during which all mealybug developmental stages (eggs, first, second and third instar nymphs, and adult females) were recorded and counted. Mealybug counts were carried out 3, 7, 14 and 21 days after insecticide application.

The density of mealybug young nymphs (first and second instar) on vine leaves was estimated 28 and 42 days after treatment, by sampling 60 randomly selected leaf/replicate (180 leaf/treatment), and counting all mealybug observed on each leaf when crawlers were moving from the trunk.

The effectiveness of the applied insecticides on mealybug populations was evaluated according to the Abbott's formula:

$$\% \text{ efficacy} = [(T_0 - T_t / T_0) \text{ X } 100]$$

where T_0 = number of alive VM on untreated vines (control) and T_t = number of alive VM on treated vines.

Statistical analyses

Densities of VM adult females, eggs, L1-L2 and L3 nymphs found on vines after insecticide treatment were transformed [Arcsin $((\sqrt{x}) / 100)$] to standardize the data distribution and to stabilize the variance. The transformed Data were analyzed by One-Way ANOVA (SAS Institute INC., Cary, NC). Means were separated using the Least Significant Differences (LSD)-test at $P = 0.05$.

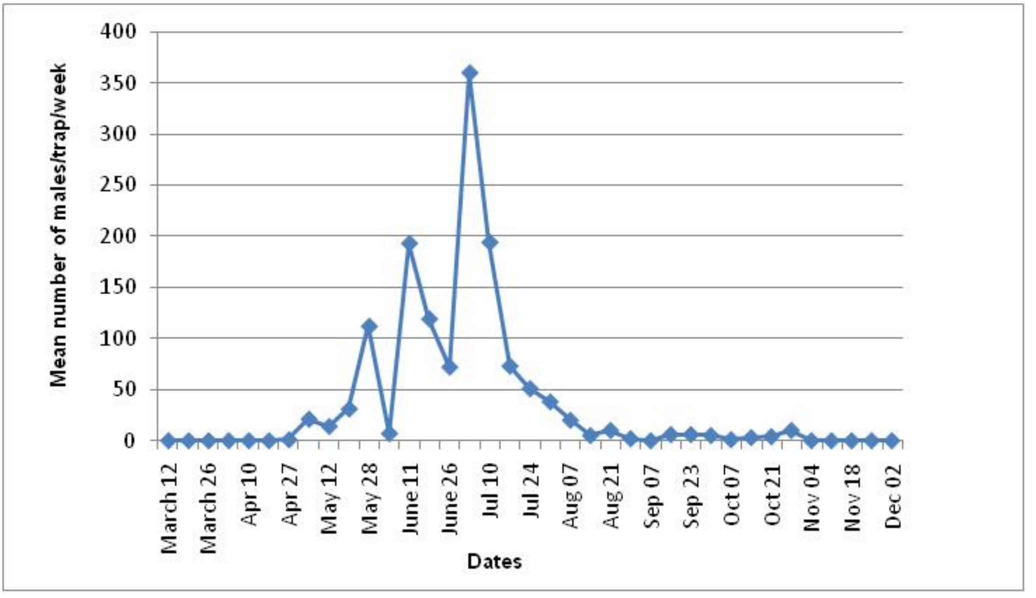

FIG. 1. Male flight activity of the vine mealybug *Planococcus ficus* in the experiment vineyard (March-December, 2008).

Results

Male flight activity

The male flight activity of the VM took place in late April and completely declined in the first week of November. Catches were initially low (< 30 males/trap/week) but progressively increased from late May to reach an average number of 112 males/trap/week. During the VM male flight period, five peaks were recorded with the two highest male counts noted in the second week of June and in early July with 193 and 360 males/trap/week, respectively (Fig. 1).

Insecticide treatments were triggered one day after the first summer VM flight peak (193 VM males/trap/week) was recorded.

Efficacy of treatments on adult females on vine trunks

The application of spirotetramat drasticcally decreased numbers of mealybug adult females on vine trunks and resulted in less mealybug abundance compared to methidathion, Prev-Am®, and imidacloprid treatments. Three weeks after treatment, Spirotetramat reduced the VM adult female population to zero, however, with more than 70% of efficacy, both Prev-Am® and imidacloprid treatments had numerically fewer VM adult females than methidathion (Table 1). Statistically, all insecticide treatments significantly (F = 17; df = 4; P < 0.0001) reduced VM adult female abundance, when compared to the untreated vines. The average density of VM adult females on vine trunks was not significantly different between methidathion, imidacloprid and Prev-Am®, while VM adult female number on spirotetramat-treated vines was significantly different from all other treatments (Table 2).

Efficacy of treatments on eggs on vine trunks

Spirotetramat proved highly effective in reducing eggs on vine trunks, compared to all other treatments. Despite its limited efficacy (< 45%) three days after treatment,

TABLE 1. Population density and efficacy (Abbott %) of insecticide treatments on VM adult females on vine trunks.

Treatment	Days following insecticide application							
	3		7		14		21	
	Density*	Abbott %	Density*	Abbott %	Density*	Abbott %	Density*	Abbott %
Untreated (control)	146	-	125	-	241	-	252	-
Methidathion	59	59.6	81	35.2	100	58.5	135	46.4
Imidacloprid	108	26	106	15.2	87	63.6	71	71.8
Prev-Am	58	60.3	64	48.8	85	64.7	67	73.4
Spirotetramat	41	71.9	13	89.6	13	94.6	0	100

*number of VM adult females/15 vine trunks; Abbott % = $[(T_0 – T_t / T_0) \text{ X } 100]$, where: T_0 = number of alive mealybugs on untreated vines (control), T_t = number of alive mealybugs on treated vines

TABLE 2. Effect of insecticide treatments on VM population densities on vine trunks compared to untreated control.

Treatment	Mealybug densities per 5-minute time search/trunk (mean ± SD)			
	adult females	**eggs**	**L1-L2**	**L3**
Untreated (control)	12.7 ± 4.34 a*	94.9 ± 17.73 a*	26.2 ± 11.48 a*	17.9 ± 3.43 a*
Methidathion	7.1 ± 1.49 b	67.9 ± 16.34 ab	12.8 ± 4.94 b	10.2 ± 1.04 bc
Imidacloprid	6.3 ± 1.33 b	76.7 ± 34.49 ab	14.9 ± 7.05 b	12.7 ± 4.7 ab
Prev-Am	5.3 ± 1.07 b	41.7 ± 21.05 bc	8.8 ± 3.18 b	6.4 ± 0.98 cd
Spirotetramat	1.1 ± 1.13 c	28.5 ± 19.55 c	13.3 ± 3.72 b	6.1 ± 3.64 d
F	17	3.58	4.74	10.49
df	4	4	4	4
P	<0.0001	0.0161	0.0041	<0.0001

*Means followed by the same letter are not significantly different (P = 0.05) within each column; SD: Standard Deviation; L1: first instar nymphs, L2: second instar nymphs, L3: third instar nymphs

spirotetramat involved a total disappearance of VM eggs, three weeks after treatment. Methidathion and imidacloprid had either no apparent or limited (< 50%) efficacy on VM eggs, contrary to Prev-Am® which reduced mealybug egg density by more than 80%, three weeks after treatment (Table 3). A significant effect of treatments (F = 3.58; df = 4; P < 0.05) was observed on mealybug egg density. Spirotetramat-treated vines had the lowest VM egg density (averaging 28.5 ± 19.55 (SD) eggs/vine trunk) which was significantly different to that recovered from Prev-Am® (41.7 ± 21.05 (SD) eggs/vine trunk), methidathion or imidacloprid treatments (Table 2).

Efficacy of treatments on L1-L2 nymphs on vine trunks

The biopesticide Prev-Am® resulted in the highest levels of VM L1-L2 nymph suppression compared to the other treatments. Three days, two and three weeks after treatment, the L1-L2 density was reduced by more than 65% on Prev-Am®-treated vines (Table 4); while, two weeks after treatment, no apparent effect on L1-L2 nymphs was supplied by imidacloprid treatment (Table 4). Statistically speaking, all insecticide treatments resulted in significantly fewer ($F = 4.74$; $df = 4$; $P < 0.05$) VM L1-L2 nymphs on vine trunks compared to the untreated control, nevertheless, no significant differrences were observed among the four insecticide treatments (Table 2).

Efficacy of treatments on L3 nymphs on vine trunks

Although they provided limited efficacy (<50%) three days after treatment, Prev-Am® and spirotetramat were found to be the most effective treatments in reducing VM L3 nymphs on vine trunks (Table 5). Three weeks after treatment, spirotetramat decreased VM L3 population by more than 90%, whereas, Prev-Am® supplied about 65% of efficacy. In contrast, both methidathion and imidacloprid resulted in higher infestation than both spirotetramat and Prev-Am® treatments, and generated less than 60% of VM L3 decrease during the post-treatment period. All treated vines had significantly ($F = 10.49$; $df = 4$; $P < 0.0001$) fewer VM L3 nymphs than the untreated. However, significantly higher VM L3 counts were found on vines treated with methidathion, imidacloprid, or Prev-Am® relative to vines treated with spirotetramat (Table 2).

Efficacy of treatments on L1 - L2 nymphs on vine leaves

Spirotetramat caused the greatest reduction in VM L1-L2 nymph numbers on vine leaves, resulting in more than 90% of efficacy, 28 and 42 days after treatment, in opposite to the other insecticide treatments whose efficacy did not exceed 60% in the same period (Table 6). Statistical analyses revealed significant impact of treatment ($F = 5.87$; $df = 4$; $P < 0.05$) on VM L1 - L2 nymph density on vine leaves. The imidacloprid, methidathion, Prev-Am® and the untreated control treatments did not differ significantly based on the abundance of VM L1-L2 nymphs on vine leaves. While spirotetramat significantly reduced the density of VM L1-L2 nymphs, which averaged 0.08 ± 0.05 (SD) /leaf, compared to the other treatments (Table 7).

Overall efficacy of insecticide treatments on VM populations

The average efficacy of each insecticide in each control date was estimated on VM populations, regardless to the developmental stage. Spiroteramat was the most effective insecticide against VM populations during all post-treatment check dates with progressive increase in its average efficacy, ranging from less than 55 ± 12.3 (SD) % three days after treatment to more than 80 ± 12.3 (SD) %, three weeks after treatment. However, during the post-treatment period, Prev-Am® proved more effective on VM populations, resulting in 73.5 ± 7.7 (SD) % of average efficacy, three weeks after treatment, when compared to both methidathion and imidacloprid (Table 8).

TABLE 3. Population density and efficacy (Abbott %) of insecticide treatments on VM eggs on vine trunks.

Treatment	Days following insecticide application							
	3		7		14		21	
	Density*	Abbott %	Density*	Abbott %	Density*	Abbott %	Density*	Abbott %
Untreated (control)	1176	-	1215	-	1615	-	1690	-
Methidathion	1252	0	705	42	950	41.2	1170	30.8
Imidacloprid	1793	0	612	49.6	880	45.5	1315	22.2
Prev-Am	800	32	965	20.6	472	70.8	265	84.3
Spirotetramat	660	43.9	488	59.8	560	65.3	0	100

***number of VM eggs/15 vine trunks; Abbott % = [(T_0 – T_t / T_0) X 100], where: T_0 = number of alive mealybugs on untreated vines (control), T_t = number of alive mealybugs on treated vines

TABLE 4. Population density and efficacy (Abbott %) of insecticide treatments on VM (L1-L2) nymphs on vine trunks.

Treatment	Days following insecticide application							
	3		7		14		21	
	Density*	Abbott %	Density*	Abbott %	Density*	Abbott %	Density*	Abbott %
Untreated (control)	578	-	495	-	285	-	212	-
Methidathion	300	48.1	172	65.2	130	54.4	168	20.7
Imidacloprid	294	49.1	241	51.3	290	0	69	67.4
Prev-Am	169	70.7	158	68.1	138	51.6	63	70.3
Spirotetramat	273	52.7	213	56.9	166	41.7	148	30.2

***number of VM (L1-L2) nymphs /15 vine trunks; Abbott % = [(T_0 – T_t / T_0) X 100], where: T_0 = number of alive mealybugs on untreated vines (control), T_t = number of alive mealybugs on treated vines

TABLE 5. Population density and efficacy (Abbott %) of insecticide treatments on VM L3 nymphs on vine trunks.

Treatment	Days following insecticide application							
	3		7		14		21	
	Density*	Abbott %	Density*	Abbott %	Density*	Abbott %	Density*	Abbott %
Untreated (control)	203	-	267	-	274	-	329	-
Methidathion	170	16.2	163	38.9	135	50.7	147	55.3
Imidacloprid	165	18.7	157	41.2	296	0	144	56.2
Prev-Am	106	47.8	79	70.4	90	67.1	111	66.2
Spirotetramat	104	48.7	157	41.2	81	70.4	25	92.4

***number of VM L3 nymphs/15 vine trunks; Abbott % = [(T_0 – T_t / T_0) X 100], where: T_0 = number of alive mealybugs on untreated vines (control), T_t = number of alive mealybugs on treated vines.

Discussion

Methidathion, an Insect Cholinesterase Inhibitor, supplied limited control performance on VM populations, resulting in less than 60% of average efficacy, compared to Prev-Am® and spirotetramat (Tables 7, 8). The highest performance of methidathion was observed seven days after treatment when VM L1-L2 nymph density was 65% lower than the untreated control. Similar results were found by Youssfi (2007) who showed that methidathion provided limited efficacy on mealybug populations in a Tunisian (Cap-Bon) vineyard. This is presumably because the mealybug's ability to protect itself, especially under the bark trunk (cryptic behavior) and waxy excretions which covers its body resulted in the inability of this insecticide to achieve contact with the pest. Besides, it might be possible that the VM developed resistance to methidathion, due to its frequent use in Tunisian grape-growing areas. Flaherty et al. (1982) suggested that the multivoltinous character of mealybugs and the frequent application of inefficient control measures accelerate the development of insecticide resistance.

However, the contact biobesticide Prev-Am® proved more effective than both methidathion and imidacloprid on VM poputlations, mainly on eggs and L3 nymphs on vine trunks, and resulted in the highest level of VM L1-L2 nymph decrease on vine trunks. Nevertheless, on vine leaves, Prev-Am® had statistically similar numbers of VM L1-L2, comparable to imidacloprid, methidathion, and untreated treatments. This finding leads us to believe that a single application of Prev-Am® is inadequate to limit further spread of VM populations. Therefore, a second foliar application of this biopesticide at about mid-July could probably enhance VM decrease and supply sufficient control of these insects until harvest.

On the other hand, the systemic insecticide imidacloprid, applied through furrow-irrigated system, resulted in VM density levels statistically close to those recovered from methidathion treatment and higher than those observed in Prev-Am® and spirotetramat-treated vines. The limited efficacy of imidacloprid is likely related to its mode of application, through furrow-irrigated system, which could involve a significant loss of this product in the soil, contrary to the case of a drip irrigated system which allows a well pick-up of the insecticide by the vine's root system and a non loss of the applied product in the soil. Daane et al. (2006) indicated that furrow-irrigated vines have a more widespread root zone, which makes delivery of the insecticide to the entire root zone difficult and results in a more dilute application and poorer uptake of the applied product. Accordingly, in California vineyards, imidacloprid provided the greatest reduction in cluster damage caused by the VM when applied in April or in May through drip-irrigation system, compared to imidacloprid applied in a furrow-irrigated system (Daane et al. 2006). Moreover, in Tunisia, a single summer application of imidacloprid through drip irrigated system allowed a significant decrease, reaching 100%, of mealybug populations in Cap-Bon vineyards (Youssfi 2007).

The Lipid Biosynthesis Inhibitor insecticide spirotetramat, applied as foliar treatment, was shown to be the most effective pesticide based on the reduction of mealybug populations. Three weeks after treatment, the application of spirotetramat resulted in an outstanding level of control when VM egg and VM adult females totally disappeared from spirotetramat-treated vines (Tables 1, 3).

TABLE 6. Population density and efficacy (Abbott %) of insecticide treatments on VM (L1-L2) nymphs on vine leaves.

Treatment	Days following insecticide application			
	28		42	
	Density*	Abbott %	Density*	Abbott %
Untreated (control)	289	-	108	-
Methidathion	166	42.5	45	58.3
Imidacloprid	224	22.5	52	51.8
Prev-Am	139	51.9	75	30.5
Spirotetramat	23	92	8	92.6

*number of VM (L1-L2) nymphs/180 leaves; Abbott % = [(T_0 – T_t / T_0) X 100], where: T_0 = number of alive mealybugs on untreated vines (control), T_t = number of alive mealybugs on treated vines.

The highest average of efficacy of this insecticide on VM populations on vine trunks was obtained three weeks after treatment, resulting in 73.55 ± 7.74 (SD) % of VM decrease (Table 8). Besides, spirotetramat significantly reduced VM L1-L2 nymphs on vine leaves by more than 90% up to 42 days after treatment. This finding clearly reveals a long-residual activity of this insecticide on VM populations. Brück et al. (2009) stated that a single application of spirotetramat against mealybugs in some grape-growing areas in the USA, Mexico, South Africa and Europe (Spain, Portugal and Greece) provided an interesting long lasting protection until harvest. In fact, since mealybugs are both cryptic and sucking pests (phloem feeders), systemic insecticides such as spirotetramat, that has a 2-way up and down systemic activity within plant to be consumed by mealybugs on any part of the vine, might have an advantage over contact insecticides.

Forty-two days after treatment, a noteworthy decrease of VM L1-L2 nymph densities was noticed on leaves, including those of untreated vines. Three reasons could be considered to explain this observation. First, at about mid-July, the majority of VM population moved from leaves to bunches to ensure its food. Second, it might be possible that there was an important degree of VM predation by larvae of the Green Lacewing

TABLE 7. Effect of insecticide treatments on VM population densities on vine leaves compared to untreated control.

Treatment	(L1- L2) nymph densities /leaf (mean ± SD)
Untreated (control)	1.1 ± 0.71 a*
Methidathion	0.8 ± 0.67 a
Imidacloprid	0.6 ± 0.24 a
Prev-Am	0.6 ± 0.48 a
Spirotetramat	0.08 ± 0.05 b
F	5.87
df	4
P	0.0042

*Means followed by the same letter are not significantly different (*P* = 0.05); SD: Standard Deviation; L1: first instar nymphs, L2: second instar nymphs

TABLE 8. Overall efficacy (Abbott % ± SD) of insecticide treatments on VM populations on vine trunks.

Treatment	**Days following insecticide application**			
	3	7	14	21
	Abbott % ± SD	Abbott % ± SD	Abbott % ± SD	Abbott % ± SD
Methidathion	30.97 ± 27.63	45.32 ± 13.53	51.2 ± 7.38	38.3 ± 15.49
Imidacloprid	23.45 ± 20.3	39.32 ± 16.67	27.27 ± 32.34	54.4 ± 22.44
Prev-Am	52.7 ± 16.67	51.97 ± 23.05	63.55 ± 8.35	73.55 ± 7.74
Spirotetramat	54.3 ± 12.27	61.87 ± 20.2	68 ± 21.69	80.65 ± 33.82

SD: Standard Deviation

Chrysoperla carnea Steph. (Neuroptera: Chrysopidae) frequently found on investigated leaves. Third, the high temperatures of July could have a drastic impact on VM L1-L2 nymphs. Indeed, in California (Coachella Valley) vineyards, a dramatic decline in VM density was reported in the summer and was perhaps due to increased mortality due to high temperature (Anonymous 2003).

In conclusion, our results revealed high performance of spirotetramat for VM control, as compared to the other insecticides. Moreover, this work showed the importance of knowing the differences in susceptibilities of VM developmental stages to insecticides. This could be very useful to determine the most accurate timing for insecticide application and to choose the appropriate insecticide for adequate VM control. Assuming that Prev-Am® resulted in the highest level of VM L1-L2 nymph decrease on vine trunks and spirotetramat proved the most effective against VM adult females, these two pesticides with different spectrum of activity, could be successfully incorporated together in an IPM program and applied early in the season before VM population has overlapping generations. In that context, the practical use of the mealybug pheromone-trap can help in early detection of VM and in the accuracy of the suitable control moment for mealybugs. Additionally, insecticide treatment should be triggered in close relation to the primary distributed VM developmental stage on vine. Further studies assessing the side effects of the tested insecticides on VM natural enemies could drastically contribute to refine IPM strategies against mealybugs in Tunisian vineyards.

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Αξιολόγηση της αποτελεσματικότητας νέων εντομοκτόνων για την καταπολέμηση του ψευδόκοκκου της αμπέλου *Planococcus ficus* στην Τυνησία

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ΠΕΡΙΛΗΨΗ

Οι ψευδόκοκκοι (Hemiptera: Pseudococcidae) προκαλούν σοβαρές οικονομικές απώλειες σε πολλές αμπελουργικές περιοχές στην Τυνησία. Σε μια προσπάθεια βελτίωσης των στρατηγικών διαχείρισης του ψευδόκοκκου της αμπέλου *Pseudococcus ficus* (Signoret), αξιολογήθηκαν 3 εντομοκτόνα, imidacloprid, Prev-Am και spirotetramat, για την αποτελεσματικότητά τους στο είδος αυτό σε σχέση με το methidathion. Το διασυστηματικό εντομοκτόνο spirotetramat (Movento® 150 OD) έδωσε την μεγαλύτερη αποτελεσματικότητα σε σύγκριση με το εντομοκτόνο επαφής methidathion, το διασυστηματικό imidacloprid που εφαρμόστηκε στα αυλάκια ποτίσματος και με το νέο βιοεντομοκτόνο επαφής Prev-Am. Τρεις εβδομάδες μετά την εφαρμογή, δεν υπήρχαν αυγά του ψευδόκοκκου και ενήλικα θηλυκά στα κλήματα όπου είχε εφαρμοστεί το spirotetramat. Ακόμη, το spirotetramat, είχε μεγάλη υπολειμματική δράση για τους πληθυσμούς του ψευδόκοκκου και εμπόδισε την περαιτέρω εξάπλωσή τους στα φύλλα της αμπέλου. Επομένως, το νέο αυτό διασυστηματικό εντομοκτόνο θα μπορούσε να συμπεριληφθεί σε ένα πρόγραμμα Ολοκληρωμένης Διαχείρισης για την καταπολέμηση του ψευδόκοκκου στους αμπελώνες της Τυνησίας. Παρά τη μικρή υπολειμματικότητά του το Prev-Am® φάνηκε να είναι πιο αποτελεσματικό τόσο από το methidathion όσο και από το imidacloprid, κυρίως για τα αυγά του ψευδόκοκκου και τις νύμφες 3^{ης} ηλικίας και είχε ως αποτέλεσμα τη μέγιστη μείωση του αριθμού νυμφών 1^{ης} και 2^{ης} ηλικίας στους βλαστούς της αμπέλου. Συνεπώς και το βιοεντομοκτόνο αυτό θα μπορούσε να αποδειχθεί χρήσιμο για την διαχείριση του ψευδόκοκκου σε αμπελώνες.