Acaricide Resistance in *Tetranychus urticae* (Acari: Tetranychidae) Populations From Cyprus

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ABSTRACT Five field and greenhouse populations of the twospotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), were collected from five different districts across the island of Cyprus, both in field and greenhouse crops, and tested to determine levels of resistance. Standard leaf-disk spray application bioassay procedures were used to determine the LC_{50}s for five chemicals: abamectin, acrinathrin, fenazaquin, pirimiphos methyl, and bifenazate. Selection of these compounds was based on the widespread use by farmers as well as on the frequent control failures against *T. urticae* reported in the past. Resistance of *T. urticae* was detected to abamectin, acrinathrin, fenazaquin, and pirimiphos methyl. The resistance ratios were calculated relative to the German susceptible reference strain. The highest resistance ratios at LC_{50} value were recorded for abamectin in a greenhouse rose population (RR = 3822), followed by a field bean (RR = 1356) and field tomato population (RR = 1320). Significantly high resistance levels were also found for acrinathrin where the highest resistance ratios at LC_{50} were recorded in a field bean *T. urticae* population (RR = 903). For fenazaquin, the highest resistance levels were recorded in a field tomato population (RR = 310). Lower resistance levels were found for pirimiphos methyl ($13.3 < RR < 77.4$) in all populations. Low susceptibility of *T. urticae* was observed for bifenazate ($2.7 < RR < 24.4$) in all populations. These results suggest that at least the use of abamectin and acrinathrin should be avoided or minimized for the control of *T. urticae* populations in indoor and outdoor environments.

KEY WORDS abamectin, acrinathrin, bifenazate, fenazaquin, pirimiphos methyl

The twospotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) is a cosmopolitan phytophagous species and the most destructive within the family of the Tetranychidae. *T. urticae* is one of the economically most important pests in a wide range of outdoor and protected crops in Cyprus and worldwide. Its host range exceeds 800 plant species (Migeon and Dorkeld 2010). This species mainly causes significant damage to ornamentals, greenhouse and outdoor vegetables, cotton, maize, flowers, legumes, deciduous trees, vines, citrus, etc. (Jeppson et al. 1975, Regev and Cone 1976, Kasap 2005). *T. urticae* is particularly dominant and destructive in intensive, high-yield cropping systems, and affects crops by direct feeding. In severe infestations, it reduces the area of photosynthetic activity and causes leaf abscission (Gorman et al. 2002). Populations can increase rapidly especially during hot and dry periods. In Cyprus, *T. urticae* may develop 15–20 generations per crop of outdoor cultivation and up to 30 generations, in greenhouses (Vassiliou and Kitsis 2011).

T. urticae control is largely based on the use of acaricides and insecticides. These compounds play a major role in the management of twospotted spider mite and other phytophagous mites in many agronomic crops (Nauen et al. 2001). This species is often difficult to manage because of its high reproductive potential, very short lifecycle, and arrhenotokous parthenogenesis, in combination with frequent insecticide and acaricide applications that often leads to development of resistance (Luczynski et al. 1990, Van Pottelberge et al. 2009, Van Leeuwen et al. 2010).

A large number of compounds with a different chemical structure and mode of action have been used against *T. urticae,* worldwide. Since the first serious and widespread outbreaks of spider mites populations, during the 1950s, organophosphorous and other neuroactive insecticides were replaced by specific acaricides. Several generations of structurally diverse synthetic acaricides, directed against various biochemical and physiological targets, as well as a number of insecticides with considerable acaricidal activity, such as pyrethroids, avermectins, and benzoylureas, have been widely used against twospotted spider mite around the globe (Jeppson et al. 1975, Knowles 1997, Dekeyser 2005, Van Leeuwen et al. 2009, Van Leeuwen et al. 2010). Most of the modern acaricides such as the Mitochondrial Electron Transport Inhibitors (METIs), organotins, and ketoenols are more specific acaricides and exert their effectiveness through disruption of respiratory processes, the growth and development of mites (Dekeyser 2005, Krämer and

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Table 1. Twospotted spider mite collection sites, dates, host plants, and cropping system

Collection site/district	Collection date	Crop	No. of applications before collection[a]			
			OPs	Pyr	Avm	METIs
Arediou/Nicosia	24 Feb. 2010	Rose (G)	24	24	24	12
Kellaki/Lemesos	15 July 2010	Cucumber (G)	10	10	10	20
Kiti/Larnaca	21 Dec. 2010	Tomato (F)	0	0	4	0
Xylofagou/Ammochostos	29 Oct. 2010	Tomato (F)	0	0	1	0
Argaka/Paphos	20 Oct. 2010	Beans (F)	2	2	2	3

The application history is also displayed.
[a] No. of applications in the sampling crops grouped by mode of action (OPs, organophosphates; Pyr, pyrethroids; Avm, avermectins; METIs, mitochondrial electron transport inhibitors).
G, greenhouse crop; F, field crop.

Schirmer 2007). Although newer compounds with acaricidal activity are often commercialised, older ones continue to be widely used by farmers, because of their low cost price.

Since the 1990s, many populations of the twospotted spider mite have developed global resistance against several new acaricides and insecticides (Arthropod Pesticide Resistance Database, http://www.pesticideresistance.org/). The persistent exposure of *T. urticae* to diverse pesticides to contain it below economic threshold has resulted in resistant populations in >40 countries and to at least 85 different compounds, both in greenhouse and outdoor crops (Georghiou and Lagunes-Tejeda 1991, Stumpf and Nauen 2001).

Acaricide resistance in phytophagous mites is a seriously increasing phenomenon, especially in *T. urticae* and other Tetranychids that have a remarkable potential for rapid evolution of resistance (Croft and van de Baan 1988, Van Leeuwen et al. 2009). Given this unfavorable development, twospotted spider mite effective management is difficult in many agricultural systems (Jeppson et al. 1975). In addition, twospotted spider mite populations have often developed a high degree of resistance to newly introduced compounds after few years of use, with cross-resistance reported to other compounds with the same mode of action.

Genetically similar *T. urticae* populations are usually found in crops under greenhouse conditions. In this environment, the resistance development is even faster because of the prolonged growing season, lack of natural enemies, and higher frequency of applications (Cranham and Helle 1985). Control failures have been reported for organophosphorous compounds for many decades as well as to other active ingredients, such as clofentezine, hexythiazox, abamectin, and tebufenpyrad (Nauen et al. 2001).

The development of insecticide and acaricide resistance is influenced by many factors, including genetics, biology and ecology, and control operations (Georghiou and Taylor 1977). These are usually classified based on their biochemical and physiological properties, as either mechanisms of decreased response to the pesticides (interaction of a pesticide with its target site), or mechanisms of decreased exposure (penetration, distribution, metabolism, and excretion) (Roush and Tabashnik 1990, Feyereisen 1995). The complexity of acaricide resistance in twospotted spider mite populations may not be explained by a single mechanism. Cross-resistance and the inheritance of resistance are not necessarily common to localities in this mite species. This suggests that each selection process leads, possibly, to a different type of resistance mechanism, depending on the location and past selection history, and may yield different cross-resistance patterns (Osakabe et al. 2009).

This study is a part of a project aiming to approach the issue of *T. urticae* control in Cyprus under the perspective of integrated pest management (IPM). This is the first research conducted in Cyprus aiming to study the resistance of this mite species to different insecticides and acaricides. The particular task involved the determination at a national level, the resistance of *T. urticae* to organophosphates, pyrethroids, avermectins, and METI compounds, the major acaricide and insecticide classes extensively used for its management in the country. Here, we present the resistance levels recorded to five selected compounds, in greenhouse and outdoor *T. urticae* populations across Cyprus.

Materials and Methods

Mite Strains. Five *T. urticae* populations were collected from both outdoor and greenhouse crops as shown in Table 1 and Fig. 1. The application history was determined by interviews. Most of the populations were collected from February to December 2010. Mites were collected from at least 20 different sampling spots at each site and were immediately

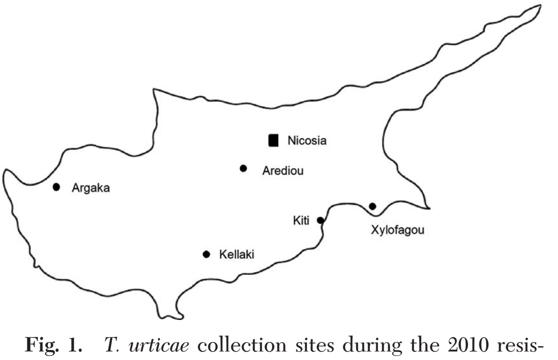

Fig. 1. *T. urticae* collection sites during the 2010 resistance monitoring survey in Cyprus.

transferred to the laboratory in a cooling box within a few hours of collection.

These populations were compared for resistance with the German susceptible reference strain (GSS). This susceptible strain was initially collected on bean [*Phaseolus vulgaris* (L.)] (Nauen et al. 2001), and it has been maintained in the absence of acaricides for the past 40 yr. For the purpose of this study, GSS was obtained from the Plant Protection Institute of Heraklion of Crete, Greece, where it was maintained on bean plants in the laboratory under controlled conditions (26 ± 1°C, 60–65% relative humidity (RH), and a photoperiod of 16:8 [L:D] h) without acaricide treatment. In Cyprus, it was reared and maintained separately in the Entomology and Toxicology laboratory of the Agricultural Research Institute, in a growth chamber on bean plants [*P. vulgaris* (L.)] of the French variety ≪Michelet longue cosse≫ at 25 ± 1°C, 65% RH, and a photoperiod of 16:8 (L:D) h.

Mites Rearing. To have sufficient mites to conduct bioassays, the collected mites from both the field and greenhouse environments were manually transferred from the sampled leaves to nontreated potted bean plants of the same variety on which the GSS was reared, placed in large insect-proof cages, and reared in a growth chamber with controlled conditions at 25 ± 1°C, 65% RH, and a photoperiod of 16:8 (L:D) h. Each population was tested for resistance within 2–3 mo of arrival at the laboratory.

Insecticides and Acaricides. All tested insecticides and acaricides were commercial formulations and were the following: pirimiphos methyl (Actellic 50 EC; AgNova Pty Technologies, Eltham, Victoria, Australia), abamectin (Vertimec 1,8 EC; Syngenta Crop Protection AG, Basel, Switzerland), acrinathrin (Rufast 7,5EW; Cheminova, Leving, Denmark), fenazaquin (Pride 200 SC; Pentagon Fine Chemicals, Halebank, Widnes, United Kingdom), and bifenazate (Floramite 240 SC; Crompton Corporation, Middlebury, CT).

Bioassays. The experiment was carried out with five concentrations and four replications for each concentration and included a de-ionized water sprayed control. Every population was tested to all active ingredients on a different day. Bean leaves were placed on wet cotton in plastic petri dishes for conducting bioassays. In each treatment, 25 females of the same age from each of the tested population and the control were used. Adult females were transferred onto the leaf using a fine (camel) brush to an insect-glue ring-shaped barrier (3–4 cm in diameter) on the upper leaf side. This was done to prevent mites from possible escape during the experimental period. The prepared suspension of each insecticide and acaricide (2 ml) was sprayed onto the leaf-disk mites, using a Potter spray tower (Burkard, Rickmansworth, Hertfordshire, United Kingdom), ensuring uniformity and accuracy in the distribution of spray liquid on the leaf. Preliminary tests showed that the aqueous compound deposit produced by the Potter spray tower, at one bar pressure was 1.6 mg/cm^2. The treated leaves were then transferred to a climatically controlled chamber and kept at the same conditions as described above.

Mite mortality was scored after 24 h. Individual mite survival was determined by touching each mite with a fine brush. Dead mites were considered those that were unable to walk at least a distance equivalent to their body length.

Data Analysis. Mortality data were corrected using the Abbott's formula (Abbott 1925) and analyzed by probit analysis to determine the lethal concentration (LC_{50}) values with respective 95% confidence limit (CL) (Finney 1971). Analysis was conducted using the Polo Plus Version 2.0 software (LeOra Software, Berkeley, CA). This software tests the linearity of dose–mortality response and provides the slope, the lethal concentrations (LC), and the 95% CL of the LC of each of the mortality line. Resistance ratios were calculated for each insecticide and acaricide by dividing the LC_{50} values of each of the active ingredient and field population by those from the susceptible GSS strain.

Results

Bioassay results are presented in Table 2. Only bioassays in which the bioassays fit the linear probit model are presented in the Table, and the calculated resistance ratios of field populations and the susceptible GSS strain were significant. Hypothesis of equality was rejected in all cases (equal or minor than $P \leq 0.05$).

Abamectin Resistance Status. Hypothesis of parallelism was rejected at $P \leq 0.05$ in the cases of the 'AREDIOU' and 'XYLOFAGOU' field strains. LC_{50} values ranged from 5.42 to 83.29 mg/liter. Population from AREDIOU exhibited the highest rate of resistance with resistance ratio RR = 3822. The 'ARGAKA' and 'KITI' populations showed also very high resistance ratios (RR = 1356 and RR = 1320, respectively). The 'KELLAKI' strain exhibited the lowest resistance ratio (RR = 248), in abamectin.

Pirimiphos-Methyl Resistance Status. Hypothesis of parallelism was rejected at $P \leq 0.05$ in the cases of the ARGAKA and XYLOFAGOU field strains. LC_{50} values ranged from 116.60 to 679.67 mg/liter. The AREDIOU population exhibited the highest rate of resistance with resistance ratio recorded at RR = 77.4, while the second highest resistance was found in the KITI population with resistance ratio RR = 40.5. The lowest resistance was exhibited in the KELLAKI population with RR = 13.3.

Bifenazate Resistance Status. Hypothesis of parallelism was rejected at $P \leq 0.05$ in the cases of the ARGAKA, KELLAKI, XYLOFAGOU, and KITI field strains. LC_{50} values ranged from 5.42 to 49.15 mg/liter. All populations exhibited high susceptibility to bifenazate with LC_{50} ranged from 2.7 < 24.4.

Fenazaquin Resistance Status. Hypothesis of parallelism was rejected at $P \leq 0.05$ in the cases of the KELLAKI and XYLOFAGOU field strains. LC_{50} values ranged from 49.08 to 4,902 mg/liter. An RR = 310 was observed in the KITI population exhibiting the highest

Table 2. Log-dose probit mortality results for *T. urticae* populations tested with different insecticides and acaricides

Strain/active substance	n	LC_{50} (mg AI liter^{-1})	95% CL	Slope ± SE	χ^2	df	RR	RR (95% CL)
Abamectin								
GSS	558	0.02a[a]	0.02–0.03	2.11 ± 0.21	22.36	4		
KELLAKI	528	5.42b	4.54–6.27	2.46 ± 0.24	11.22	4	248	197–314
XYLOFAGOU	505	20.08c	14.58–26.26	1.47 ± 0.15	24.23	4	921	691–1,228
KITI	457	28.79c	15.96–41.52	1.63 ± 0.21	39.74	4	1,320	959–1,819
ARGAKA	528	29.55c	21.68–38.48	1.69 ± 0.17	28.80	4	1,356	1,038–1,771
AREDIOU	400	83.29d	73.82–92.71	5.37 ± 0.95	21.75	4	3,822	3,158–4,626
Pirimiphos methyl								
GSS	371	8.78a	5.98–11.02	4.10 ± 0.54	35.74	4		
KELLAKI	444	116.60b	98.04–133.31	4.95 ± 0.50	40.54	4	13.3	11.24–15.67
XYLOFAGOU	465	272.68c	237.14–305.99	6.28 ± 0.69	30.96	4	31	26.34–36.56
ARGAKA	474	283.54c	241.53–321.25	6.45 ± 0.93	31.45	4	32.3	27.31–38.14
KITI	430	355.55c	287.81–435	5.29 ± 0.58	73.67	4	40.5	34.37–47.63
AREDIOU	376	679.67d	599.47–782.16	5.08 ± 0.64	56.17	4	77.4	65.80–90.92
Bifenazate								
GSS	391	2.02a	1.50–2.52	3.03 ± 0.31	4.02	4		
XYLOFAGOU	481	5.42b	4.61–6.33	4.23 ± 0.38	39.95	4	2.7	2.24–3.23
KITI	475	9.82c	8.30–11.06	4.75 ± 0.58	23.63	4	4.9	4.02–5.89
ARGAKA	399	10.20c	7.76–11.99	4.16 ± 0.61	30.93	4	5.1	4.11–6.23
KELLAKI	493	12.25c	10.15–13.40	10.08 ± 1.59	41.64	4	6.1	5.13–7.20
AREDIOU	493	49.15d	39.57–58.86	3.06 ± 0.33	32.05	4	24.4	19.85–29.92
Fenazaquin								
GSS	390	15.85a	10.57–20.30	3.08 ± 0.51	36.03	4		
ARGAKA	358	49.08b	42.63–55.26	4.03 ± 0.40	23.61	4	3.1	2.51–3.83
KELLAKI	496	58.28b	50.60–64.50	6.51 ± 0.72	38.65	4	3.7	3.01–4.49
XYLOFAGOU	515	107.46c	98.20–116.54	4.88 ± 0.50	21.88	4	6.8	5.56–8.27
AREDIOU	434	2,994d	2,694–3,316	3.96 ± 0.68	11.96	4	189	153.16–233.18
KITI	504	4,902e	4,077–5,789	3.28 ± 0.42	29.27	4	310	247.77–386.30
Acrinathrin								
GSS	456	15.95a	13.34–18.05	3.35 ± 0.53	22.81	4		
AREDIOU	457	1,420b	725–2067	1.40 ± 0.32	22.62	4	89	60.98–130.07
KELLAKI	417	4,060c	3,280–4,800	3.79 ± 0.42	26.70	4	255	212.04–305.74
KITI	293	7,543d	5,807–8,830	5.07 ± 0.86	29.78	4	473	396.28–564.56
ARGAKA	458	14,400e	9,809–18,229	2.46 ± 0.35	25.64	4	903	701.63–1,161
XYLOFAGOU	410	11,850e	10,169–13,657	3.35 ± 0.45	25.65	4	743	632.86–872.29

[a] Different letters indicate nonoverlap of confidence limits ($P < 0.05$).
n, no. of mites tested.

rate of resistance to this active ingredient, while the resistance ratio in the AREDIOU population was recorded at RR = 189.

Acrinathrin Resistance Status. Hypothesis of parallelism was rejected at $P \leq 0.05$ only in the case of the AREDIOU field strain. LC_{50} values ranged from 4,060 to 14,400 mg/liter. In acrinathrin, the ARGAKA population exhibited the highest rate of resistance, with resistance ratio recorded at RR = 903. The XYLOFAGOU population showed also significant resistance with resistance ratio recorded at RR = 743, while the population from AREDIOU exhibited the lowest resistance ratio RR = 89 in this active ingredient.

Discussion

During the last decade, growers in Cyprus have reported control failures of several compounds against twospotted spider mite greenhouse and outdoor populations, but more frequent failures have been reported in greenhouse crops and ornamentals. The application of acaricides is usually required to maintain *T. urticae* populations below economic thresholds, especially in high-yield cropping systems where this mite species is dominant and destructive (Nauen and Konanz 2005). The compounds tested in our study represented the most frequently used mode of action groups registered for use against this mite species in the country, both in greenhouse and outdoor crops. However, after few years of repeated application of these products, they exhibited unsatisfactory effectiveness for complete control of *T. urticae* outbreaks in both environments. The results obtained from this study revealed the presence of resistance of *T. urticae* to four out of five compounds tested.

T. urticae is most destructive under greenhouse conditions (especially on roses), and the risk of developing resistance to abamectin (and to other compounds) is particularly higher in this environment because of the relative isolation of twospotted spider mite populations, the extended growing season, and the intensive use of pesticides. Particularly on roses and other ornamentals, the lack of regulations on pesticide residues results in intensive pesticide use. This leads to quick resistance built-up to acaricides, threatening proper rose production in this environment (Gorman et al. 2002, Khajehali et al. 2011). These practices are well experienced and documented in abamectin resistance on *T. urticae* greenhouse rose populations, both in our case in the AREDIOU strain (RR = 3,822-fold), in an Italian strain (RR = 1,294-fold) (Tirello et al. 2012), as well as in a Brazilian strain where mite mortality was <20% (Nauen et al. 2001).

Increasing levels of resistance to the most commonly used acaricides have caused multiple treatments, including overdoses. Although various aspects of abamectin resistance in *T. urticae* strains have been studied worldwide, in both greenhouse and outdoor environments (Campos et al. 1995, Beers et al. 1998, Stumpf and Nauen 2002, Sato et al. 2005, Cerna et al. 2009, Kwon et al. 2010c), there is no information about abamectin resistance levels in this pest, in Cyprus. Abamectin is a widely used by farmers broad-spectrum product with both insecticide and acaricide properties and considered safe to beneficial arthropods because of its short environmental persistence, rapid uptake into treated plants, and fast degradation of surface residues (Clark et al. 1995, Krämer and Schirmer 2007). For these reasons, abamectin remains one of the frequently used compounds for the past 20 yr for the control of twospotted spider mite and various insect pests in many indoor and outdoor crops in Cyprus, including roses and other ornamentals, strawberries, beans, tomatoes, cucumbers, etc.

In some of the aforementioned studies, it was found that resistance rate was related to the number and frequency of chemicals applied in a production season, and to the continuous use of compounds having the same effect mechanism (Campos et al. 1995, 1996). In our study, the history of applications using organophosphate, pyrethroid, avermectin, and METI acaricides against *T. urticae* populations significantly varied between these two environments (Table 1), while the number of chemical applications was not always related to high resistance. The only case justifying the relationship between the number of applications and high levels of resistance was that of abamectin (RR = 3822) in the AREDIOU greenhouse rose *T. urticae* strain. Here, the high number of applications (>80) on greenhouse roses during a growing season revealed the severity of the problem with *T. urticae* and justifies the development of resistance, especially in abamectin (24 applications), as well as in other compounds tested (except bifenazate) (Table 2).

However, there were cases in both greenhouse and outdoor *T. urticae* populations where no relationship between the number of applications and resistance levels in abamectin was found. In greenhouse environment, the lowest resistance levels in abamectin were recorded in the KELLAKI greenhouse cucumber population (RR = 248-fold), despite the high number of applications (>50) in a production season. The difference in resistance levels in abamectin on greenhouse rose and cucumber can be explained by the number of chemical applications (24 vs 10, respectively) these two crops received during a growing season, because of their different growing duration. Rose is considered a permanent ornamental in a greenhouse environment, whereas cucumber can be planted twice per season, or alternatively, it can be rotated with other crops. Subsequently, the rose *T. urticae* population received higher chemical pressure compared with the strain on cucumber.

Totally different situation was observed in the resistance to abamectin in field crops. Taking into account that only four, one, and two applications (Table 1) with this compound have been conducted against the XYLOFAGOU, KITI, and ARGAKA field populations, respectively, the recorded resistance to abamectin was significantly high (RR = 921-, 1,320-, and 1,356-fold, respectively). This is controversial to the findings obtained by Campos et al. (1995) where no resistance among *T. urticae* populations against this compound was found in a population that had been subjected to fewer than six applications per year.

One of the explanations of the instability in resistance between the two environments may be the migration of susceptible mites from nearby outdoor crops to greenhouse cucumber or resistant mites from greenhouse to field crops. This migration of susceptible (or resistant) mites from other host plants may also affect the reestablishment of susceptibility in both environments (Miller et al. 1985, Dunley and Croft 1992). This phenomenon is experienced in the case of cucumber. As it is a common practice adopted by the majority of Cypriot owners of polyethylene greenhouses (connected gutter or free Quonset) when temperature increases within the greenhouse, they leave open the polyethylene film windows and other parts of the greenhouse for better ventilation. These types of greenhouses have no ventilation systems and no site nets for preventing *T. urticae* or other pests from entering or leaving the greenhouse.

High resistance levels in Cypriot *T. urticae* populations were also recorded in the pyrethroid acrinathrin. A number of pyrethroid insecticides are frequently used for the control of phytophagous mites. Previous studies reported high levels of pyrethroid resistance in *T. urticae* populations worldwide, with resistance levels scaling >2,000 folds (Tsagkarakou et al. 2009, Van Leeuwen et al. 2009). In Cyprus, acrinathrin is widely used the last 15 yr for the control of insect and mite pests mostly in outdoor crops. According to our results (Table 2), significantly high levels of resistance at LC_{50} were recorded to this compound, mainly in *T. urticae* outdoor strains (473 < RR < 903). Similar resistance levels (RR = 329) were found to acrinathrin in a Korean apple *T. urticae* strain (Kim et al. 2006).

Although a number of resistance mechanisms to different classes of insecto-acaricide compounds in *T. urticae* have been recently characterized at a molecular level (Tsagkarakou et al. 2009; Khajehali et al. 2011; Van Leeuwen et al. 2010; Kwon et al. 2010a,b; Dermauw et al. 2012), the avermectin and pyrethroid resistance mechanisms were not studied in this resistance monitoring study of the present research, and therefore, it is not possible to confirm the existence (or lack) of cross-resistance with other acaricides.

Early detection of resistance of *T. urticae* to insecticides and acaricides is a crucial element in the resistance management system to supress or delay resistance development. Depending on the growing environment (indoor or outdoor), control measures against *T. urticae* may vary. In greenhouse crops, release of beneficial organisms, including predatory mites such as *Phytoseiulus persimilis* (Canestrini and Fanzago) and *Neoseiulus californicus* (McGregor)

(Acari: Phytoseiidae) may give good results in controlling resistant *T. urticae* populations. In outdoor crops preservation of natural enemies is important. In both cases, acaricide applications (under IPM programs) may be necessary to suppress twospotted spider mite populations; however, selective use of acaricides that are compatible with natural enemies may preserve predator populations and enhance control.

Undoubtedly, the 3,822-fold resistance recorded to abamectin in the greenhouse rose AREDIOU strain, as well as the high resistance levels found to other compounds tested, in both greenhouse and outdoor *T. urticae* populations, highlights the fragile and worrisome situation for its effective control, in Cyprus. The use of novel acaricides with distinct modes of action (as they become registered) may help in controlling resistant twospotted spider mite populations, both in greenhouse and outdoor environments and readily become part of resistance management programs. One of the strategies to prolong the efficacy of abamectin and acrinathrin in both environments is the rotation with other compounds with acaricidal effect, such as sulfur, fenpyroximate, propargite, clofentezine, tebufenpyrad, hexythiazox, bifanazate, spiromesifen, etc. The data obtained from this study can be used as a basis for future resistance *T. urticae* monitoring programs in Cyprus.

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