The European Journal of Plant Science and Biotechnology ©2008 Global Science Books

Bio-ecology and Control of *Pezothrips kellyanus* (Thysanoptera: Thripidae) on Citrus in Cyprus

Vassilis A. Vassiliou*

Agricultural Research Institute, Plant Protection Section, P.O. Box 22016, 1516 Nicosia, Cyprus

Correspondence: * **vassilis@arinet.ari.gov.cy**

ABSTRACT

Kelly's citrus thrips is one of the most common thrips species found in Cyprus citrus orchards. Kelly's citrus thrips larvae were the sole insect stage causing feeding damage mainly on immature lemon and grapefruit fruits. Under Cyprus conditions Kelly's citrus thrips adults prefer to concentrate mostly in the northern and eastern sides of both lemon and grapefruit canopies. The recorded mean number of adults in the northern side of lemon canopies was 60.7, followed by eastern – 48.4 adults ($F_{0.05\ (3,\ 32)} = 2.431$; $P< 0.083$; Mean sq. = 2952.60), while on grapefruit canopies was 45.3 and 30.8 adults ($F_{0.05\ (3,\ 32)} = 4.237$; $P< 0.012$; Mean sq. = 2578.30) in the northern and eastern sides, respectively. In 2006, damage of lemon and grapefruit fruits reached 64.0% and 45.8%, respectively, while in 2007 damage was recorded at 50.4% and 91.2%, respectively. Depending on weather conditions and pest's abundance, the first chemical spraying should be applied 10-20 days after massive petal fall and calyx closure at the fruitlet stage, and the second one-two weeks after the first application. Various insecticides were evaluated in field trials in lemon and grapefruit plantations against Kelly's citrus thrips. Statistically significant differences were observed in 2006 and 2007. In 2006, the best protection of lemons provided by the neonicotinoid acetamiprid (93.0%) and the carbamate methiocarb (79.7%), while on grapefruits the most effective insecticides were acetamiprid (95.1%) and the macrocyclic lactone spinosad (75.7%). In 2007, acetamiprid and the Insect Growth Regulator lufenuron provided 85.1% and 82.2% protection of lemons, respectively, while on grapefruits best results were obtained with acetamiprid and the organophosphate chlorpyrifos providing 86.5% and 84.1% protection, respectively.

Keywords: chemical control, damage, distribution, grapefruit, insecticides, lemon

INTRODUCTION

Citrus is one of the most important crops in Cyprus. The area under citrus is about 5543 ha, representing 4.1% of the total cropped area and 15% of the irrigated land. The main citrus varieties cultivated in Cyprus are: oranges - 57.2%, lemons - 16.4%, grapefruits - 10.4%, mandarins and other varieties - 16%. The International literature provides very scarce information about the biology, the ecology and the management of Kelly's citrus thrips (KCT) as this is a new pest. The main objective of this work was to study the bio-ecological peculiarities and test various insecticides for the control of KCT under Cyprus field conditions. In this study, we present the results of the cardinal distribution and the efficacy of various active ingredients of insecticides against KCT, applied in lemon and grapefruit orchards.

Kelly's citrus thrips (KCT) *Pezothrips kellyanus* (Bagnall) became an economic pest on citrus plantations in Cyprus in the last decade. The pest was recorded for the first time in 1996 in the coastal citrus plantations of the Limassol and Paphos districts and caused serious damage (scarring around the calyx), mainly on lemon and grapefruit fruits (Orphanides 1998). The pest was also recorded in Australia in 1914 (Bagnall 1916), in New Zealand in 1950 (Mound and Walker 1982), in Greece in 1981 (Palmer 1987; zur Strassen 1986), in Turkey and Spain (zur Strassen 1996), in Southern Italy (Marullo 1998), in Portugal (zur Strassen 2003), and Southern France (Moritz *et al*. 2004). In these countries, KCT causes serious damage on citrus fruits every year.

It remains unclear if the pest is a species of European citrus that was introduced into Australia or was an Australian endemic pest that changed its host associations and habits, and recently migrated to Europe. The Australian host plant data reveal that the pest is an Australian native insect (Webster *et al*. 2006).

Limited information is available about the biology and management and this is because KCT is a relatively new citrus pest. *P. kellyanus* is a polyphagous flower-living species. The females lay eggs on flower parts, mainly in the

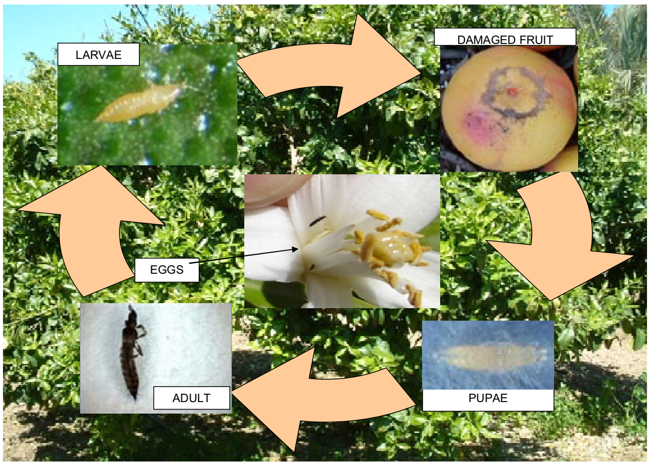

Fig. 1 Life cycle of Kelly's citrus thrips *Pezothrips kellyanus*. Life cycle of KCT consists of eggs, two larval stages (I and II), pre-pupae, pupa and adult. The information we provide regarding KCT's life cycle is not a result of our research but it is obtained from available studies that conducted in Australia and New Zealand. Development stages of KCT and their duration depend on the season. In spring, the average number of days required for the development of one generation is about 25-28 days, in summer -14 and in winter – 70-80. KCT adults are in high numbers in spring during the main flowering period of citrus.

Received: 1 April, 2008. Accepted: 13 April, 2008.

Original Research Paper

petals (**Fig. 1**). The pest pupates exclusively in the soil (Jamieson and Stevens 2006; Webster *et al*. 2006). After emerging in the spring, adults and larvae feed on pollen and nectar. There are two larval instars - I and II. KCT abundance peaks in citrus orchards during the main flowering period in spring (Baker *et al*. 2002). This species develops up to six generations per year (EPPO 2004).

The pest prefers to feed in sheltered areas such as under the calyx, between touching fruit, and where a leaf or a twig touches the fruit. In serious cases of damage, the scarring can cover the entire fruit. Lemons appear to be the most important source and refuge for KCT and this is due to their sporadic flowering throughout the year. Low populations of KCT have been recorded on mandarin and Valencia orange flowers (Blank and Gill 1997).

Since its appearance, KCT has become a serious citrus pest in Cyprus, causing scarring damage on citrus fruits (Orphanides 1998). The damage is caused by the two larval instars. This species feeding on immature fruit causes a silvery, ring-like form thin layer of scarring (halo) on the fruit surface, mainly around the calyx area of the developing fruit-let. Lemons appear to be very susceptible to *P. kellyanus* (Froud *et al*. 2000), followed by oranges (navel and Valencia) and grapefruit (Baker *et al*. 2004). In New Zealand, KCT larvae were commonly found on immature lemon fruits, navel orange and tangelo. In Greece, 70% of citrus fruits in Chania (Crete, Greece) showed a typical scarring damage caused by KCT (Varikou *et al*. 2002). In eastern Sicily, the larvae have caused serious feeding damage on immature fruits of lemons and oranges (Conti *et al*. 2001a). Despite the insecticide applications (one to five) against KCT, an average of 20–40% of the fruit can remain unsaleable to the fresh fruit markets (Baker 2007). Infested fruits are considered unacceptable for export, even though the presence of the scars affects only the appearance and not the quality of the fruit.

KCT populations in citrus orchards can be reduced with insecticides (Baker *et al*. 2004; Martin 2005; Vassiliou 2007) and some soil-dwelling predatory mite species and parasitoid insects (Baker *et al*. 2005). Reliance only on insecticides can lead to development of resistance. Resistance to chlorpyrifos has been reported from South Australia, resulting in field control failures (Purvis 2002).

MATERIALS AND METHODS

This research was conducted at the Acheleia Experimental Station in the Paphos district (Western coastal area of the island) in 2006-2007. The Experimental citrus plantations at the Station cover an area of 10 ha. The main citrus varieties sampled for KCT presence were the following: *Citrus sinensis* Osbeck - oranges (common, navel, red), *Citrus paradisi* Macf - grapefruits - (red and white), *Citrus maxima* (Burm) - pummelo, *Citrus reticulata* Blanco – mandarins, *Citrus limon* Burm. - lemons, and *Citrus medica* Linn. - citron.

Canopy distribution

The distribution of thrips on lemon and grapefruit trees canopy was studied. The main sampling and observations were gathered from late February to late June, mainly on mature lemon (19 years-old) and grapefruit (17 years-old) trees. Counts of thrips in flowers were conducted weekly on 10 randomly selected trees in the lemon and grapefruit orchards (2 and 3 ha, respectively). From each tree, 40 randomly distributed flowers from the periphery of the canopy (10 from the eastern, 10 from the southern, 10 from the northern and 10 from the western sides) were examined (without removing them) for the presence of adult thrips, using a 10X hand lens. These counts were initiated in early spring when the first flowers on the lemon and grapefruit trees appeared and lasted until the end of flowering.

Insecticide field trials and fruit damage evaluation

The chemical applications were conducted in lemon and grapefruit varieties only. The planting distances were as follows: lemons – 8 × 8 m; grapefruits – 8 × 5 m. No buffer trees were used.

In lemons there were a total of 11 treatments - 10 treatments with the active ingredients tested and 1 treatment used as a control (no insecticides were applied). Each treatment included 1 row of 12 trees with two replications.

In grapefruits there were a total of 12 treatments – 11 treatments with the active ingredients tested and 1 treatment used as a control (no insecticides were applied). Each treatment included 1 row of 16 trees with two replications.

All active ingredients were applied in early morning and in full calmness (no wind) in order to avoid insecticide drifting. The first application in grapefruits (2 May, 2006; 7 May, 2007) and lemons (3 May, 2006; 8 May, 2007) was conducted during the massive larvae appearance that coincides with the fruit-let formation, and the second one, two weeks after the first application (lemons – 16 May, 2006 and 22 May, 2007; grapefruits – 15 May, 2006 and 21 May, 2007, respectively). Insecticides that have been tested every year and found to have low effectiveness against KCT were replaced with other active ingredients.

In order to evaluate the efficacy of the applied insecticides, two insecticide applications with the same active ingredient were conducted as follows: the first one, 10-20 days after massive petal fall (at fruit-let formation) by spraying all trees on the rows, and the second one, two weeks after the first application, by spraying half the number of trees in the row for comparison.

For application of insecticides a high pressure applicator Unifarm (Udor Srl, 42048, Via A. Corradini 2, Rubiera, Italy) with capacity of 500 L was used. The tank is equipped with two hoses of 50 m each and a Gamma-95 high pressure plunger pump (maximum pressure – 60 bar; flow rate – 73.5 L/min). The chemical applications have been conducted by using simultaneously two high pressure spraying guns with standard nozzle (2 mm) for general foliage spraying of insecticides. Approximately 25 L of spray per tree was applied and the spraying pressure used in our trials was 2.5 bars.

During harvesting in December, damage caused by KCT was evaluated by selecting randomly one hundred fruits from the boxes (collected from each tree in the treatment and the control) and examining them for scar damage, mainly around the calyx. Scars were classified as either slight or severe (a severe scar was any that would cause the fruit to be not suitable for export).

Insecticides

All active ingredients used in field trials were commercially available and have approval for use in citrus against various pests. The commercial product based on entomopathogenic fungi *Beauveria bassiana* is registered for use as a biological insecticide. Application rates used in field trials were those recommended on the label by the manufacturer. All insecticides and the application rates used in field trials in 2006-2007 are presented in **Table 1**.

Statistical methods

All statistical analyses and comparisons were performed by SAS (SAS 2002). Because of unequal subclass numbers, GLM procedure was employed to analyse the data. Mean ($P < 0.05$) comparisons were performed using the Tukey's test. In order to normalize the damage percentage, the ARCSINE transformation was adopted to transform the real damage.

RESULTS

Canopy distribution

Direct sampling of lemon and grapefruit flowers conducted in 2006 and 2007 indicated that the distribution of thrips in the canopy was not uniform; the pest prefers to concentrate mostly in the eastern and northern sides of the canopy (**Table 2**). The results from the statistical analysis revealed significant differences in KCT's cardinal distribution on lemon and grapefruit canopies in 2006-2007. The recorded mean number of adults in the northern side of lemon canopies was 60.7, followed by eastern – 48.4 adults ($F_{0.05\ (3,\ 32)}$

Table 1 Insecticides and application rates used in field trials against Kelly's citrus thrips in 2006-2007. Acheleia Experimental Station.

Year	Active ingredient	Commercial name	Company	Dose [b]	g a.i. L^{-1}
2006-2007	chlorpyrifos	Dursban® 48% EC	DowAgroSciences, Indianapolis, USA	1.5 cc	1.07
2006-2007	lufenuron	Match® 5% W/V	Syngenta, Madrid, Spain	1.5 cc	0.12
2006	methiocarb	Mesurol® 75 WP	BayerCropScience, Leverkus., Germany	2.0 g	1.85
2006	diazinon	Basudin® 600 EC	Syngenta, Madrid, Spain	1.5 cc	0.99
2006-2007	[a]methomyl	Lannate® 90 SP	DuPont, Newark, USA	0.6 g	0.69
2006-2007	dichlorvos	Divipan 100 EC	Makhteshim–Agan, Omer, Israel	1 cc	1.42
2007	acrinathrin	Rufast® 6 EC	Cheminova, Lemvig, Denmark	1 cc	-
2006-2007	spinosad	Tracer® 48% EC	DowAgroSciences, Indianapolis, USA	0.3 cc	0.07
2006-2007	acetamiprid	Mospilan® 20SP	Nippon Soda, Sharda, Japan	0.5 g	0.13
2006	*B. bassiana*	Naturalis L	Troy Biosciences Inc, Arizona, USA	1.5 cc	-
2007	thiamethoxam	Actara® 25 WG	Syngenta AG, Basel, Switzerland	0.15 g	-
2007	abamectin	Vertimec® 1,8% EC	Syngenta AG, Basel, Switzerland	0.5 cc	0.10
2006-2007	paraffinic oil	U.F. Oil, 98.8%	Sun Company Inc., Philadelphia, USA	6 cc	5.09

[a] 1 g L^{-1} of sugar has been added to this active ingredient
[b] L^{-1} of water

Table 2 Canopy distribution of Kelly's citrus thrips on 10 lemon and 10 grapefruit trees by examining 40 flowers from the periphery (10 from each of the cardinal direction). Acheleia Experimental Station, 2006-2007.

Side	KCT adults [a]	
	Lemon [b]	Grapefruit [c]
North	60.7 a	45.3 a
East	48.4 ab	30.8 ab
South	28.4 b	15.0 b
West	24.1 b	9.9 b

[a] Means within each column with the same letter are not significantly different at 5%, according to Tukey's Test.
[b] $F_{0.05\,(3,\,32)} = 2.431$; $P< 0.083$; Mean sq. = 2952.60
[c] $F_{0.05\,(3,\,32)} = 4.237$; $P< 0.012$; Mean sq. = 2578.30

= 2.431; $P< 0.083$; Mean sq. = 2952.60), while the recorded mean number on grapefruit canopies was 45.3 and 30.8 adults in the northern and eastern sides, respectively ($F_{0.05\,(3,\,32)} = 4.237$; $P< 0.012$; Mean sq. = 2578.30). No statistically significant differences on canopy distribution were observed between the southern and western sides on both the lemon and grapefruit canopies.

Insecticide field trials and fruit damage evaluation

During 2006-2007, a series of insecticides with different mode of action were evaluated, aiming to find the most effective in controlling the KCT populations and reducing the damage in lemons and grapefruits caused by this pest. KCT populations in lemons and grapefruits during the examined years were present in high numbers that could cause serious damage (**Fig. 2**). This finding was a result of the population monitoring and trapping which has conducted in experimental and commercial citrus orchards, mainly in lemon and grapefruit varieties.

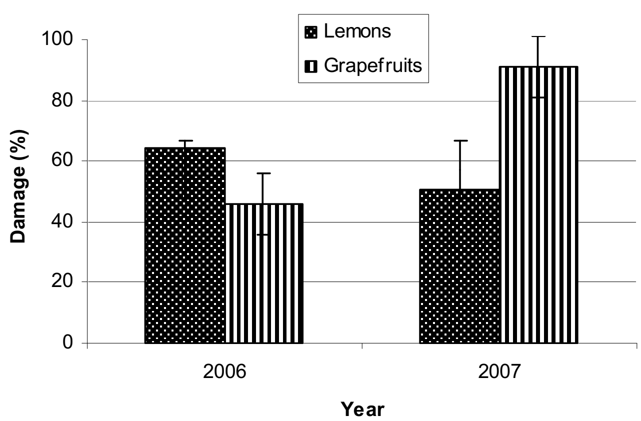

Fig. 2 Damage of lemons and grapefruits in control treatments in 2006-2007.

The insecticides found so far to be the most effective after two applications against KCT are shown in **Table 3**. The level of efficacy of the applied insecticides has been observed to vary year-by-year in lemons and grapefruits. The statistical analyses showed that the treatment differences in years 2006 and 2007 were highly significant. In 2006, acetamiprid and methiocarb gave the best results providing 93.0% and 78.7% protection of lemons, respectively ($P< 0.0001$; transformed damage - $F_{0.05\,(10,\,83)} = 9.82$; real damage - $F_{0.05\,(10,\,83)} = 6.87$), while on grapefruits the best results were obtained from acetamiprid and spinosad providing 95.1% and 75.7%, respectively ($P< 0.0001$; transformed damage - $F_{0.05\,(11,\,166)} = 8.94$; real damage - $F_{0.05\,(11,\,166)} = 5.76$). Other active ingredients such as chlorpyrifos (net) and lufenuron provided 46.3% and 72.8% protection of lemons and grapefruits, respectively. In 2007, acrinathrin gave the best results providing 85.1% protection of lemons, followed by lufenuron with 82.2% protection ($P< 0.0001$; transformed damage - $F_{0.05\,(10,89)} = 8.54$; real damage - $F_{0.05\,(10,89)} = 8.27$), while on grapefruits the best protection 86.5% was given by acetamiprid, followed by chlorpyrifos (net) with 84.1% protection ($P< 0.0001$; transformed damage - $F_{0.05\,(11,\,160)} = 37.77$; real damage - $F_{0.05\,(11,\,160)} = 41.70$).

DISCUSSION

Flower sampling in the field showed that KCT is an active pest that prefers to concentrate mostly in the eastern and northern sides of both lemon and grapefruit canopies. The blooming in lemon trees, compared to grapefruit and other citrus varieties, is not uniform. The 2006-2007 experimental trials have shown that cardinal direction appeared to have a significant effect on species distribution on the canopy. The two likely explanations that can be offered for this phenomenon are the following: the first one is that these sides of the canopy (eastern and northern) are in shadowed areas most of the time throughout the day and KCT adults avoid direct sunlight, especially when the temperatures are high; the second one is that this higher concentration perhaps has to do more with the wind direction and speed. On the island of Cyprus, mainly in the coastal areas where the majority of citrus are grown, frequent and relatively high west and south-west winds blow, mainly during spring (flowering period) and summer. South and south-west winds were predominant at the trial site of the Experimental Station over the course of this study. Other investigators (Lewis 1997) have shown that thrip's flying activity and directionality of flight is strongly influenced by atmospheric conditions, mainly by wind direction. Obviously, KCT adults are concentrating mostly on eastern and western sides of the canopies in order to avoid direct wind. These observations will be further studied in detail at a later time, in conjunction with the fruit damage caused by KCT on these sides.

Since 1996, when the pest was first found in Cyprus citrus groves, many field trials were conducted aiming to determine the most optimum timing for spraying. The insecti-

Table 3 Insecticide effectiveness against Kelly's citrus thrips on lemons and grapefruits (combined results from two replications). Acheleia Experimental Station.

Citrus species	**2006**			**2007**		
	Treatment	**Damage** [a]		**Treatment**	**Damage** [a]	
		Real	**Transf.**[b]		**Real**	**Transf.**[c]
Lemon	dichlorvos	81.8 a	9.0 a	abamectin	70.0 a	8.3 a
	diazinon	65.8 a	8.0 a	dichlorvos	66.1 a	8.1 a
	lufenuron	64.9 a	7.8 a	chlorpyrifos [d]	55.9 ab	7.2 ab
	control	64.0 a	7.9 a	methomyl	52.0 ab	7.0 ab
	spinosad [e]	63.8 a	7.9 a	chlorpyrifos (net)	51.9 ab	7.0 ab
	chlorpyrifos (net)	61.4 a	7.8 a	control	50.1 abc	6.9 ab
	B. bassiana	59.7 a	7.5 a	spinosad [e]	38.6 abcd	6.1 abc
	methomyl	55.4 ab	7.1 a	thiamethoxam	27.0 bcd	4.6 bc
	chlorpyrifos [d]	53.7 ab	7.1 a	acetamiprid	19.0 cd	4.0 c
	methiocarb [d]	21.3 bc	4.2 b	lufenuron	17.8 cd	3.9 c
	acetamiprid	7.0 c	2.4 b	acrinathrin	14.9 d	3.7 c
Grapefruit	control	45.8 a	6.7 a	control	91.9 a	9.6 a
	dichlorvos	43.9 a	6.3 ab	lufenuron	81.0 a	8.9 ab
	diazinon	39.6 a	6.1 ab	dichlorvos	56.9 b	7.5 bc
	chlorpyrifos (net)	40.6 a	6.0 ab	acrinathrin	56.8 b	7.5 c
	chlorpyrifos (net)	38.8 a	6.0 ab	clorpyrifos (net)	50.3 b	6.9 c
	B. bassiana	34.8 a	5.8 ab	spinosad	49.2 b	6.9 c
	chlorpyrifos [d]	31.7 a	5.5 ab	abamectin	44.4 bc	6.6 cd
	ethiocarb [d]	31.0 a	5.5 ab	methomyl	30.3 cd	5.3 de
	methomyl	27.7 a	5.1 ab	thiamethoxam	24.7 d	4.9 ef
	lufenuron	27.2 a	5.1 ab	chlorpyrifos [d]	23.0 d	4.7 ef
	spinosad [e]	24.3 ab	4.7 b	chlorpyrifos	15.9 d	3.8 f
	acetamiprid	4.9 b	2.0 c	acetamiprid	13.5 d	3.6 f

[a] Means within each column with the same letter are not significantly different at 5%, according to Tukey's Test.
[b] In lemons, the F values for the transformed and real damage for 2006 were: $F_{0.05\,(10,\,83)} = 9.82$; $F_{0.05\,(10,\,83)} = 6.87$; $P < 0.0001$, respectively, and for 2007 - $F_{0.05\,(10,89)} = 8.54$; $F_{0.05\,(10,89)} = 8.27$; $P < 0.0001$, respectively.
[c] In grapefruits, the F values for the transformed and real damage for 2006 were: $F_{0.05\,(11,\,166)} = 8.94$; $F_{0.05\,(11,\,166)} = 5.76$; $P < 0.0001$, and $F_{0.05\,(11,\,160)} = 37.77$; $F_{0.05\,(11,\,160)} = 41.70$; $P < 0.0001$ for 2006 and 2007, respectively.
[d] To these active ingredients, 5.09 g a.i. L^{-1} of Ultra Fine Oil was added.
[e] To this active ingredient, 2.54 g a.i. L^{-1} of Ultra Fine Oil was added.

cides were applied in different stages of flowering and fruitlet formation. Very low or no effect on KCT populations was observed when chemicals were applied in 50% of flowering and full flowering (Charalampous, P. 2006 pers. comm.) of lemon and grapefruit species. During these flowering stages, the incidence of KCT larvae is very limited.

The variability in effectiveness of various insecticides both in lemons and grapefruits throughout the examined years can be explained by prevailing weather conditions (such as strong winds, rain, and low night temperatures) that take place during the flowering period in the experimental area. Three basic factors were taken into consideration in order to determine the most suitable timing of applications: a) the massive presence of larvae, b) the flowering stage of the variety and its duration and, c) the absence of wind. Under Cyprus conditions, the most crucial period for damage is during the first 10-20 days after petal fall to calyx closure (Vassiliou 2007). The duration of this stage varies year by year and depends exclusively on weather conditions. All insecticides were applied 2-3 weeks after massive petal fall and mainly against the larval stages (instars) I and II.

Fruit damage depends also on pest density. KCT's population density appears to depend on the citrus variety, the presence and abundance of flowers, and the duration of flowering stage. Population densities of KCT in citrus groves are very high during the main flowering period and very low during the winter season. The flowering stage of grapefruits is more uniform, short and simultaneous compared to the flowering stage of lemons which is not uniform, and is long-lasting. Lemon varieties flower sporadically throughout the year, and appear to be an important feeding source and refuge for KCT populations. According to our results no significant differences in damage of both the untreated lemon and grapefruit fruits caused by KCT were observed. The only exception was observed in 2005 where damage in lemons was approximately 18% higher compared to grapefruits while in 2007, damage in grapefruits was approximately 41% higher compared to lemons (Vassiliou 2007). Other investigators (Marullo 1998; Conti *et al.* 2001a; Varikou *et al.* 2002; EPPO 2004) have shown that damage caused by KCT in lemons is more severe than in other citrus crops.

The very good protection of lemons and grapefruits obtained by some active ingredients such as acetamiprid, lufenuron, chlorpyrifos, spinosad, and acrinathrin was probably the result of interplay of factors affecting the population densities of the pest and minimising the damage risk. Before conducting the chemical applications the following factors were considered: 1) that the peak of the massive appearance of larvae was identified (after a detailed scouting and trapping). The length and intensity of the scurfing risk period varies from year to year due mainly to variation in pest's abundance. Based on that, the chemicals were applied only during the massive appearance of larvae; 2) that prevailing weather conditions, mainly the absence of rain and wind were known. As it was stated earlier this species prefers to concentrate mostly in the northern and eastern sides of the canopy. This is likely the result of strong winds that prevail in the island every year mainly during the citrus flowering period in spring, and 3) that all active ingredients that could be used in trials, should have approval for use in citrus and labels indicating their effectiveness against different thrips species.

During the examined years, we observed that the populations of various insect pests increased after two applications with some insecticides. Outbreak of California red scale *Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae), cottony cushion scale *Icerya purchasi* (Maskell) (Homoptera: Margarodidae), and citrus mealybug *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) on lemons and grapefruits was observed after treatment with thiamethoxam. Outbreak of citrus rust mite - *Phyllocoptruta oleivora* (Ashmead) (Acari: Eriophyidae), citrus wooly whitefly - *Aleurothrixus floccosus* (Maskell) (Homoptera:

Aleyrodidae), oriental spider mite *Eutetranychus orientalis* Klein (Acari: Tetranychidae), and California red scale *Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae) was observed after two treatments with acetamiprid. High populations of purple scale *Lepidosaphes beckii* Newman (Homoptera: Diaspididae) have been recorded after two consecutive years of treatment with methomyl. Similar situation was observed with California red scale *Aonidiella aurantii* (Maskell) after two treatments with spinosad.

The results of the effectiveness of the evaluated insecticides suggest that the chemical control of thrips on citrus should be done between the second and third week after massive petal fall. The flowering and fruit-let duration vary year by year and depend exclusively on weather conditions.

Since resistance to insecticides (chlorpyrifos) has been reported (Purvis 2002) all insecticides that were found to be effective against KCT populations should be rotated in the context of an IPM programme in order to minimise the risk of resistance development. Botanical and biological substances will continue to play a major role in field trials and their evaluation for effectiveness will be further studied. In this context we are aiming to find biological agents and substances that will be effective under Cyprus conditions, protecting thus, the environment and public health from the unfavourable consequences from the use of toxic synthetic active ingredients.

ACKNOWLEDGEMENTS

The Acheleia's Experimental Station and the Plant Protection Section's staff is acknowledged for their assistance in conducting this study.

REFERENCES

Bagnall RS (1916) Brief descriptions of new Thysanoptera VII. *Annual Magazine of Natural History* (8) **17**, 213-223

Baker G, Jackman D, Keller M, MacGregor A, Purvis S (2002) Development of an Integrated Pest Management system for thrips in *Citrus*. HAL Final Report CT97007, 125 pp

Baker G, Keller M, Purvis S, Jackman D, Crisp P (2004) Improving the management of Kelly's Citrus Thrips in citrus: Summary, conclusions and recommendations of the 2000-04. KCT research project. Available online: http://www.sardi.sa.gov.au/pages/ento/hort_pests/kct_report00_04.htm

Baker GJ, Keller MA, Crisp P, Jackman D, Barbour D, Purvis S (2005) The biological control of Kelly's citrus thrips in Australia citrus orchards. Poster at the *15th International IFOAM Organic World Congress 'Shaping Sustainable Systems'*, SARDI and University of Adelaide (Eds), 20-23 Sept., Adelaide, Australia

Baker G (2007) Small mites play big role in controlling citrus pest. SARDI Riverlink Newsletter, Autumn, 80 pp

Blank RH, Gill GSC (1997) Thrips (Thysanoptera:Terebrantia) on flowers and fruit of citrus in New Zealand. *New Zealand Journal of Crop and Horticultural Sciences* **25**, 319-332

Conti F, Tuminelli R, Amico C, Fisicaro R, Raciti E, Frittitta C, Perrotta G, Marullo R (2001a) Monitoring *Pezothrips kellyanus* on citrus in eastern Sicily. Thrips, Plants, Tospoviruses: The Millennial Review. In: *Proceedings of the 7th International Symposium on Thysanoptera*, 1-8/7, Reggio Calabria (Italy), pp 207-210

EPPO Reporting Service (2004) *Pezothrips kellyanus* a new citrus thrips: addition to the EPPO Alert List 2004/137, 9 pp

Froud K, Stevens P, Steven D (2000) Kelly's citrus thrips 2. Evaluating a potential monitoring system. *The Orchardist* **73 (10)**, 60-63

Jamieson LE, Stevens PS (2006) The effect of mulching on adult emergence of Kelly's citrus thrips (*Pezothrips kellyanus*). *New Zealand Plant Protection* **59**, 42-46

Lewis T (1997) Flight and dispersal. In: Lewis T (Ed) *Thrips as Crop Pests*, CAB International, Cambridge, pp 175-196

Martin NA (2005) Pesticide Resistance: Prevention and Management Strategies 2005. Published by the New Zealand Plant Protection Society Inc., Hastings, New Zealand. Available online: http://ww.nzpps.org/resistance/thrips.php

Marullo R (1998) *Pezothrips kellyanus* un nuovo thripide parassita delle culture meridionali. *Informatore Fitopatologico* **10**, 72-74

Moritz G, Mound LA, Morris DC, Goldarazena A (2004) Pest thrips of the world –Visual and Molecular Identification of Pest Thrips. CD-Rom. CBIT, Brisbane, Australia

Mound LA, Walker AK (1982) Terebrantia (Insecta:Thysanoptera). *Fauna of New Zealand* **1**, 120

Orphanides G (1998) Thrips on citrus. Annual Review for 1997. Agricultural Research Institute, Nicosia, Cyprus, 38 pp

Palmer JM (1987) *Megalurothrips* in the flowers of tropical legumes: a morphometric study. In: Holman J, Pelikan J, Dixon AFG, Weismann L (Eds) *Population Structure, Genetics and Taxonomy of Aphids and Thysanoptera*, SPB Academic Publishing, The Hague, Netherlands, pp 480-495

Purvis S (2002) Are KCT developing resistance to chlorpyrifos? Talking thrips in citrus October 2002 issue **2**, 1. Available online: http://www.sardi.sa.gov.au

SAS (2002) JMP Statistical V.4.0.2 for Windows. SAS Institute Inc., Cary, NC

Varikou K, Tsitsipis JA, Alexandrakis V, Mound L (2002) *Pezothrips kellyanus* (Bagnall) (Thysanoptera: Thripidae), a new pest of citrus trees in Crete, In: *Proceedings of the VIIth European Congress of Entomology*, Thessaloniki (Greece), p 33

Vassiliou AV (2007) Chemical control of *Pezothrips kellyanus* (Thysanoptera: Thripidae) in citrus plantations in Cyprus. *Crop Protection* **26 (10)**, 1579-1584

Webster WK, Cooper P, Mound L (2006) Studies on Kelly's citrus, *Pezothrips kellyanus* (Bagnall) (Thysanoptera: Thripidae): sex attractants, host associations and country of origin. *Australian Journal of Entomology* **44**, 67-74

zur Strassen R (1986) Thysanopteren auf inselen der Nordlichen Sporaden in der Agais (Griechenland). *Seckenbergiana Biologica* **67 (1/3)**, 85-129

zur Strassen R (1996) Neue daten zur Systematik und Verbreitung einiger west-paläarktischer Terebrantia-Arten (Thysanoptera). *Entomologische Nachrichten und Berichte* **40**, 111-118

zur Strassen R (2003) Die Terebranten Thysanoptera Europas und des Mittelmeer – Gebeties. *Die Tierwelt Deutschlands* **74**, 277