



E-ISSN: 2320-7078

P-ISSN: 2349-6800

JEZS 2016; 4(2): 109-114

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Received: 19-01-2016

Accepted: 21-02-2016

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An analysis of western flower thrips *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) in lemons: Its abundance, distribution and damage status

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Abstract

Abundance, distribution of thrips species occurring on citrus as well as damage level of western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) is studied in Yenice, Tarsus, Turkey during 2013-2014. As a result, 10 different thrips species were investigated. Thrips fauna was dominated by the *F. occidentalis* having 98.25% of total adult of the thrips population. The coefficient of determination (r^2) of Taylor indices ranged from 0.62 and 0.92 for larvae and 0.43 and 0.92 for adult *F. occidentalis*. The values coefficient b of Taylor were always less than 1 (two-tailed t test, $P < 0.0001$), indicating a regular population distribution. Majority of larval or adult *F. occidentalis* was detected in flowers. The highest thrips densities with mean of 6 or 7 individuals (larvae+adult) per flower in nontreated plots did not cause any damage to flowering parts or developing fruits. Spraying of citrus lemon against thrips is not warranted.

Keywords: *Frankliniella occidentalis*, lemon, abundance, distribution

1. Introduction

Many thrips (Thysanoptera) species are known attacking *Citrus* spp. (Rutaceae) in different parts of the world [1, 2]. These species generally cause feeding damage on flowers, fruits and leaves of citrus varieties and the damage is characterized by silvery scars on the tissues around calyx which decrease market value [3]. The most important thrips pest attacking citrus species are *Scirtothrips citri* (Moulton) (citrus thrips) in California (USA), *Scirtothrips aurantii* Faure (South African citrus thrips) in South Africa [4], *Scirtothrips dorsalis* Hood (Yellow thrips) in East Asia [5], and (KCT) *Pezothrips kellyanus* (Bagnall) (Kelly's citrus thrips) in Australia [6], New Zealand [7] and in two Mediterranean island Sicily [8] and Cyprus [9]. However, Longo [10] indicated that there are more than 40 thrips species dwelling citrus, and only a few thrips including *Scirtothrips* spp. and *Thrips tabaci* Lindeman are recognized as pests of citrus, by scarring young fruits.

In Turkey species composition of thrips inhabiting citrus has been well-documented [11, 3]. According to Nas *et al.* [11] and Ölçülü and Atakan [12] thrips species have not been regarded as pests of citrus in the eastern Mediterranean region of Turkey. However *Frankliniella occidentalis* (Pergande), *Thrips major* Uzel and *Thrips tabaci* Lindeman were found commonly in citrus plantations [13, 12]. *F. occidentalis* is a polyphagous species infesting many crops and wild plants worldwide. This thrips was recorded for the first time on some ornamentals and vegetable plants in Antalya, Turkey in 1993 [14]. After its introduction this thrips spread quickly almost all part of Turkey and caused damage on vegetables, ornamental plants and stone fruit trees especially in the Çukurova Region. On the other hand *F. occidentalis* was found most abundant thrips species dwelling citrus flowers in Çukurova region [12]. However chemical applications are not authorized for thrips pest in citrus, even there are grievance on thrips damage in the region (Tarsus and Mersin) from citrus growers particularly on lemon (*Citrus limon* (L.)). Chemical application is common to control thrips at flowering stage in the region. Although some studies stated that *F. occidentalis* was not regarded as a pest in citrus in Italy [15] and Cyprus [9] there is no information regarding thrips damage particularly on lemons without any insecticide application.

On the other hand, Kelly's citrus thrips, *Pezothrips kellyanus* (Bagnall) which is known as a serious pest of citrus worldwide particularly in Mediterranean Countries, is less common and

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less abundant in the eastern and western Mediterranean region of Turkey. *P. kellyanus* scarred only 6% of developing Limon fruits in Hatay province, Turkey [12]. Recently, few numbers of this pest thrips were observed in citrus flowers.

Integrated pest management studies on citrus in the region showed that citrus orchards have a rich beneficial insect fauna of attacking various insect pests and acari in citrus [16, 17]. Heavily and unnecessary pesticide use against thrips particularly at flowering period of citrus in the region may lead to occurrence of some ecological problems such as destroying natural enemies and developing insect resistance against pesticides. For this reason standardized sampling protocols are important elements for pest management decision-making [18]. A sampling technique which allows quick and accurate estimates of the density of pest arthropod populations is critical in evaluating pest abundance against established economic thresholds. The plant part preference and spatial distribution of *F. occidentalis* in lemon trees in Turkey or other countries is not well-known. However, distribution pattern of *P. kellyanus* on lemon trees in Spain has been documented by Navarro-Campus *et al.* [19]. Standardized sampling protocols are important elements for pest management decision-making [18].

In this study, we aimed to investigate plant part preference and spatial distribution *F. occidentalis* and to determine its damage to lemon fruitlets. Achieved data may provide a contribution to integrated pest thrips control strategies in citrus in the region.

2. Materials and Methods

2.1. Experimental design

All trials were carried out in Yenice, Mersin, Turkey during the years 2013 and 2014. The experimental area of 5-years-old Meyer lemon (almost 0.4 ha) was surrounded by various fruit crops, such as nectarines and oranges. The distance between trees was 5x3 meters. Experimental area was divided equally into two main sections to constitute treated and non-treated main plots. Each main plots consist of two rows of 40 trees (each row contain 20 trees). Each main plot also was divided into 4 sub-plots for replications. Each sub-plot consists of 2 rows with 10 trees. Biological pesticide spinosad (Laser 480g/l) was applied at recommended dose (20 ml per 100 lt water) against thrips in treated plots by using portable atomizer (Mori THP-250) with 25 lt tank capacity. Atomizer was operated at 10.0 bars and 500 ml water per tree was used approximately. Two Insecticide applications were done in one week interval during the flowering season in both years (with spinosad on April 17 and 24 in 2013 and April 8 and 15 in 2014). No buffer trees or rows were used. All applications were applied in early morning.

2.2. Insect sampling procedure

Materials used in this study are thrips material, thrips collection such as white tray dishes and fine brush, and preparation equipments such as petri dishes, alcohol, sodium hydroxide etc.

Thrips samplings were made from 17 April until 15 May (total of 5 consecutive sampling dates) in 2013 and from 8 April until 6 May (total of 5 consecutive sampling dates) in 2014 when the plants were blooming stage and early fruit formation. Thrips counts on lemon flowers were conducted at week intervals. 50 new citrus flowers and/or early stage fruits were randomly taken from exterior part of the canopy of citrus trees (five flowers or fruits per tree from 10 randomly selected trees) in each sub-plot. Five flowers or fruits were put into one plastic vial (50 cc) containing 70% ethyl alcohol. In total 1200

or 1600 flowers and 400 or 800 fruitlets from each of two main plots in sampling years were collected. Flower and fruitlet samples were stored in tubes and transported to the laboratory for further processing. For extraction of insects, flowers and early stage fruits were submerged into 60% ethanol and shaken for 25 seconds. Flowers were dissected carefully to remove any remaining thrips and rinsed in 60% ethanol for 25 seconds. Thrips extracted from the flowers and early stage fruits were transferred into small vials (2 ml) containing 60% ethanol for subsequent processing. Thrips were slide-mounted by using the method of Kirk [20] and identified by the Ekrem Atakan. Thrips adults were counted under the stereomicroscope with 45x magnifications, and immature thrips (thrips larvae) were pooled into a single category.

2.3. Effect of thrips on fruit size

In order to qualify effect of thrips on early stage fruits size, 10 randomly selected early stage fruits from each sub-plot of treated and nontreated plot. Totally 40 fruits from each main plots were taken and put into plastic bags. Samples of early stage fruits were taken on 15 May and 30 May in 2013, and 6 May and 20 May in 2014. Diameters (mm) of early stage fruits were measured in laboratory and recorded to determine if there is a difference between fruits collected from different applications.

2.4. Dispersion pattern

The spatial distribution patterns of both larvae and adult stages of *F. occidentalis* on different plant parts were examined using Taylor's power law (TPL). Taylor's power law parameter, $Log_{10}(s^2) = \log(a) + b \log(m)$,

Where the intercept a is a sampling constant and slope b is an aggregation index characteristic for species and host [21]. Estimates of a and b were obtained by regressing s^2 on m using the logarithmic transformation of both s^2 and m . According to this model, distributions can be broadly classed as regular ($b < 1$), random ($b = 1$) or aggregated ($b > 1$) [22].

2.5. Data analysis

A repeated measure analysis (RM-ANOVA) was used to examine effect of sampling dates and different interactions (Table 1). A general liner model (GLM) was used to determine effect of insecticide treatment and year on densities of *F. occidentalis* (larvae and adult) (Table 2). A simple student-t test was used to compare mean densities of larval or adult thrips in treated and nontreated plots at $P < 0.05$ importance level. Data obtained from flowers and early stage fruits were pooled over a sampling date to determine plant part-preference of larval or adult thrips in 2013. Same test was used to compare mean numbers of thrips from flowers and fruits. Differences between treated and nontreated plots for fruit size in diameter were separated by use of simple student t-test at $P < 0.05$. All analyses were performed by using the Microsoft statistical program (SPSS 15.0 [23]).

3. Results

3.1. Composition and abundance of thrips

In this study, 10 thrips species from three different families were found (Table 1). The species are listed with their abundance (total numbers of individuals collected for a given species) (Table 1). While major species were from the family Thripidae, species from the family Aeolothripidae was only representative. The thrips fauna was dominated by *F. occidentalis* with 98.25% of total adults. Percentages of other

Thysanoptera species were less than 1% in total individuals. The total number of *Haplothrips reuteri* Priesner with 35

individuals was relatively high in 2013. There was no individual of thrips belonging to Aeolothripidae in 2014.

Table 1: Species composition of thrips and their numbers in lemon flowers during 2013-2014

Family	Thrips species	2013	2014	Total	Percent
Thripidae	<i>Frankliniella occidentalis</i> ((Pergande)	2486	1593	3979	98.25
	<i>Thrips tabaci</i> Lindeman	21	2	23	0.56
	<i>Thrips major</i> Uzel	5	0	5	0.13
	<i>Limothrips cerealium</i> Haliday	3	1	4	0.10
	<i>Pezothrips kellyanus</i> Bagnall	2	0	2	0.05
	<i>Frankliniella intonsa</i> (Trybom)	1	0	1	0.01
	<i>Thrips meridionalis</i> Priesner	1	0	1	0.01
Phlaeothripidae	<i>Haplothrips reuteri</i> (Karny)	34	0	34	0.83
	<i>Haplothrips distinguendus</i> Uzel	2	0	2	0.05
Aeolothripidae	<i>Aeolothrips collaris</i> Priesner	1	0	1	0.01

3.2. Plant part preference of western flower thrips

The total mean numbers of larvae and adults per flower both on treated (larvae: $t = 7.428$, $df = 78$, $P < 0.001$; adult: $t = 13.992$, $df = 78$, $P < 0.001$) and non-treated plants (larvae: $t = 7.434$, $df = 78$, $P < 0.001$; adult: $t = 13.014$, $df = 78$, $P < 0.001$) in 2013 was significantly higher than those on early stage fruits (Fig: 1). Few numbers of larvae or adult were observed on early stage fruits samples.

3.3. Thrips abundance

Year 2013

Planting dates and various interactions affected significantly thrips abundance, excluding insect stage and interaction year \times insect stage (Table 2). Seasonal trends of both larvae and adults in *F. occidentalis* population were similar in both applications. Mean number of thrips larva was highest on

flowers on May 2 (Fig: 2). First insecticide (on April 17) treatment did not affect both larvae and adult numbers in the population (Fig: 2a). After the second insecticide treatment (on April 24), larval density drastically decreased but mean numbers of adult continued to increase with mean 16.12 ± 1.30 adult individuals per 5 flowers in treated plot. Insecticide application did not affect adult numbers in flowers. This is likely due to heavy rainfall one day later after spraying of the trees. However, larval and adult numbers on flowers in nontreated plot on May 2 were significantly greater than those on recorded in treated plots (larvae: $t = 3.100$, $df = 78$, $P = 0.003$; adult: $t = 2.170$, $df = 78$, $P = 0.033$; Fig: 2b). Mean numbers of *F. occidentalis* (larvae + adult) in treated and nontreated plots varied from 0.01 to 6.96 individuals per flower and 0.08 to 5.94 individuals per flower in nontreated plots in 2013.

Table 2: Results of repeated measure analysis done against *Frankliniella occidentalis*

Sources	df	MS	F	P
Date	4	4726.720	99.348	0.000
Date \times year	4	4426.960	93.047	0.000
Date \times treatment	4	987.318	20.752	0.000
Date \times insect stage	4	2240.302	47.047	0.000
Date \times year \times treatment	4	335.743	7.057	0.000
Date \times year \times insect stage	4	2840.102	59.715	0.000
Date \times treatment \times insect stage	4	306.940	6.451	0.000
Date \times year \times treatment \times insect stage	4	209.920	4.442	0.002
Error (date)	1248	47.578		
Intercept	1,312	46602.016	948.534	0.000
Year	1,312	1566.181	31.878	0.000
Insect stage	1,312	137.476	2.798	0.095
Year \times treatment	1,312	2354.676	47.927	0.000
Year \times insect stage	1,312	27.826	0.566	0.452
Treatment \times insect stage	1,312	161.928	3.296	0.070
Year \times treatment \times insect stage	1,312	532.456	10.838	0.001

Year 2014

Comparing results of previous year, spinosad treatments effectively suppressed both adult and larval population through sampling dates (Fig: 2a). Excluding data of April 8, adult and larval mean densities were significantly lower in treated plots on most sampling dates ($P < 0.0001$; Fig: 2b). Larval densities in treated plots ranged between 0.05 and 3.87 per 5 flowers. The highest density of adult thrips in treated plot was 3.62 ± 0.58 adults per 5 flowers. Mean numbers of WFT (larvae + adult) in treated plot varied from 0.07 to 1.50 individuals per flower. In nontreated plots larval density was the highest peaking with mean of 18.92 ± 1.33 per 5 flowers on April 29 (Fig: 2b). Larval numbers were greater than adults on most sampling dates in nontreated plots. Adults peaked in flowers

April 18 with mean of 11.10 ± 1.67 per 5 flowers. Mean numbers of WFT (larvae + adult) in nontreated plot varied from and 0.32 to 5.08 individuals per flower in nontreated plots in 2014 (Fig: 2b).

3.4. Distribution pattern

The coefficient of determination (r^2) of Taylor indices ranged from 0.62 and 0.92 for larvae and 0.43 and 0.92 for adult *F. occidentalis* (Table 3). The values coefficient b of Taylor were always less than 1 (two-tailed t test, $P < 0.001$; Table 3), indicating a regular population distribution. Values of b for larval number were similar to those of adult in treated and nontreated plots in both years.

Table 3: Regression statistics and parameter estimates for Taylor's power law against *Frankliniella occidentalis* during in 2013 -2014

Year	Plot	Plant part	Insect stage	Log (a)	b		R ²	df	F
2013	Treated	Flower	Larvae	0.58	-0.0615	REG	0.92	1,10	114.609*
			Adult	0.5173	0.1565	REG	0.43	1,10	7.803***
	Nontreated	Flower	Larvae	0.587	-0.1269	REG	0.92	1,10	117.148*
			Adult	0.578	0.0285	REG	0.92	1,10	122.185*
2014	Treated	Flower	Larvae	0.4264	0.1427	REG	0.90	1,14	302.285*
			Adult	0.5202	0.0665	REG	0.78	1,14	52.105*
	Nontreated	Flower	Larvae	0.6424	-0.2407	REG	0.95	1,14	28.972*
			Adult	0.298	0.4312	REG	0.54	1,14	16.572**
2013	Nontreated	Fruit	Larvae	0.5402	-0.1771	REG	0.62	1,6	8.422***
			Adult	1.027	0.105	REG	0.91	1,6	65.528*

*** $P < 0.0001$; ** $P < 0.001$; * $P < 0.05$.

3.5. Fruit size

Fruit size in diameter obtained from treated and nontreated plots are given in Fig: 3. There was found no differences for fruit size between treated and nontreated plot in both years, resulting in no negative effect of thrips feedings on fruit developments.

4. Discussion

All thrips species found in this study were polyphagous feeding habit. Different abundance of thrips species may be related with cultivated plants or herbaceous host plants nearby to experimental area. In this study *F. occidentalis* appeared to be the most dominant thrips species comprising 98% of total adult individuals. *F. occidentalis* was a main thrips in citrus orchards in Antalya [3]. *F. occidentalis* is found commonly at high densities on vegetables and fruit trees in the Çukurova Region. Yenice district is well-known as vegetables growing in greenhouses or open field and fruit cultivation. This thrips species has also dominated thrips fauna being on wild flora in this location. Furthermore, *F. occidentalis* adults are active in all year in the nature concerning the cropping system. Greenhouse or outdoor populations of *F. occidentalis* may have migrated to lemon flowers. Migration of polyphagous thrips from non-crop surrounding hosts into cultivated area has been showed by several authors [24, 25]. Abundance of different species possibly results from differences in the surrounding crops and wild flora. Hence, *H. reuteri* number (mostly inhabits cereals in Turkey [26]) was relatively higher in 2013 and no individual of that thrips was found in 2014 where there was no thereby wheat field in the area.

Larval and adult *F. occidentalis* showed regular distribution pattern (b value < 1; $P < 0.0001$). In contrary to our results, both *F. occidentalis* and *P. kellyanus* in Spain had clumped distribution pattern on lemon flowers and fruitlets [19]. In our case, regular distribution pattern of *F. occidentalis* is likely due to low densities of adult and larval thrips populations and they present in flowers or young fruits for a very short period. Majority of *F. occidentalis* larvae and adults captured from flowers (Fig: 1). Navarro-campus *et al.* [19] indicated that *F. occidentalis* was present in flowers but was almost absent from fruits. According to study of Navarro-campus *et al.* [19] *F. occidentalis* does not reproduce in citrus orchards. In current study, *F. occidentalis* produced adequately larvae in flowers even larval densities was two times more than adult densities on some sampling dates in treated and nontreated plots (Fig: 2). *F. occidentalis* adults visit flowers and reproduce at blossoming period of lemon but developing fruits are not attractive to both larvae and adult thrips. Similarly, *F. occidentalis* did not cause damage to citrus in southern Italy [15]. Moreover, this thrips does not scar citrus fruits in Cyprus [9]. However it was reported *F. occidentalis* being a pest of citrus in Korea [27] and Japan [28].

Few adults of *P. kellyanus* were found in the lemon flowers. *P. kellyanus* was reported for the first time in Adana province, Turkey in 1995 [11]. After passing nearly 20 years, *P. kellyanus* does not constitute population in citrus and not appear as a pest in the Çukurova Region. *P. kellyanus* scared only 6% of lemon fruitlets in Arsuz district, Hatay province located at the eastern Mediterranean region of Turkey [12]. However, *P. kellyanus* is often recognized as a serious pest of citrus mainly of lemons in several Mediterranean countries namely; Italy, Greece, Cyprus and Spain and southern Australia, New Zealand [1, 8, 29, 30, 9, 31]. *P. kellyanus* scars tissues around calyx and, causes rind blemish on young and mature fruits [1]. Mainly larvae of *P. kellyanus* is responsible for fruit damage and appears on citrus at the period from dense petal fall until the fruit reach 4 cm in diameter. Larvae does not scar the fruits when the fruits 4 cm or larger [32, 1, 19]. In current study, reason of *P. kellyanus* having very few numbers in flowers may attributable to no breeding hosts of that thrips in the region. Only adults of *P. kellyanus* were found on several flowering ornamentals such as rose in parks and home gardens in the Çukurova Region [33]. Navarro-campus *et al.* [18, 34] reported that host plants being frequent blooming and growing inside or in the vicinity of citrus orchards, such as jasmine, can sustain reproduce of *P. kellyanus* year-around.

Neither *F. occidentalis* adults nor thrips larvae does not scar developing fruitlets. However, we found a few numbers of scarred young fruits in the experimental area. This scar damage is likely due to wind. In east Mediterranean region, citrus growers misinterpret scar damage due to wind, and they attempt to use insecticides against thrips at blooming stage of citrus trees. Scars, due to thrips feedings, appear mainly around stem end of fruit, and may extend longitudinally on fruit surface; scar tissues do not include green islands of healthy or clean tissue.

As a conclusion, *F. occidentalis* dominated the thrips fauna in lemon flowers. Few adults of *P. kellyanus* were collected from the flowers. Status of *P. kellyanus* in thrips composition in citrus has been not changed since its first introduction to the region in 1995. *F. occidentalis* reproduces well only in flowers but very few numbers of *F. occidentalis* were obtained from early stage fruit samples. Although abundance of treated plots was significantly lower on most sampling dates in particular in 2015, *F. occidentalis* did not affect size of developing fruits. With respect to findings that spraying of citrus lemon against thrips is not necessary in the region.

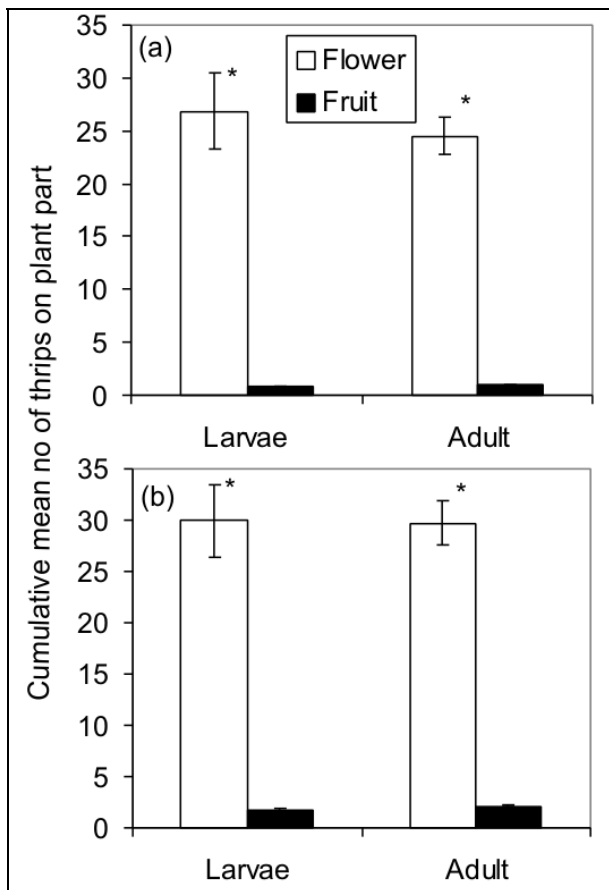


Fig 1: Cumulative mean numbers of *Frankliniella occidentalis* on different plant parts in treated (a) and nontreated plots (b) in 2013. Asterisk on the bars indicate significant level according to student-t test ($P < 0.0001$).

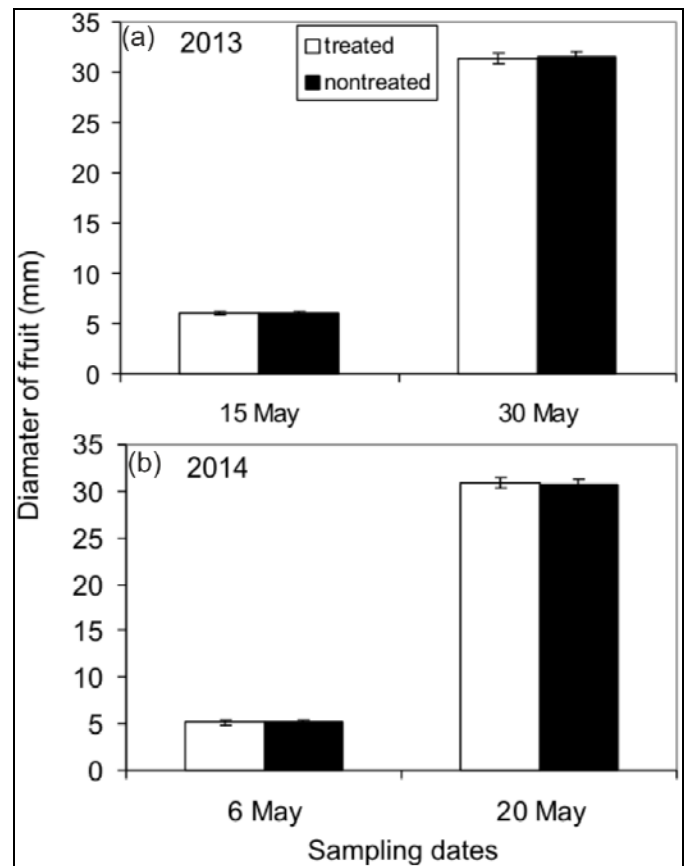


Fig 3: Size of fruits in diameter obtained from treated (a) and nontreated (b) plots during 2013-2014.

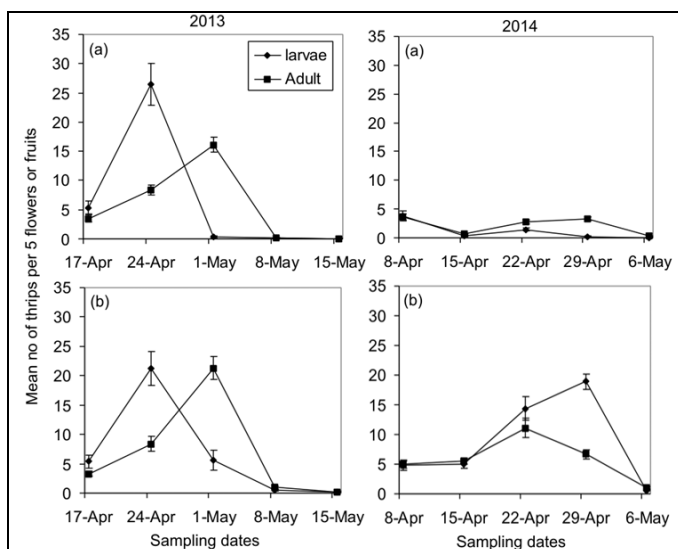


Fig 2: Mean numbers of larval and adult *Frankliniella occidentalis* on flowers and/or early stage fruit (thrips/5 flowers and/or early stage fruits) in treated (a) and nontreated (b) plots. Only fruits were sampled on 8 and 15 may in 2013 and on 15 May in 2014. Trees were sprayed with spinosad against thrips on 17 and 24 April in 2013, and 8 and 15 April 2014.

5. Acknowledgements

We would like to express our thanks to citrus grower Ahmet Doğan (Yenice, Tarsus, Mersin province, Turkey) for providing the experimental area and also to associate Prof. Dr. Bora Kaydan (Vocational School of İmamoğlu, University of Çukurova, Adana, Turkey) for reviewing of the manuscript.

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