Tarım Bilimleri Dergisi
Tar. Bil. Der.

Dergi web sayfası:
www.agri.ankara.edu.tr/dergi

Journal of Agricultural Sciences

Journal homepage:
www.agri.ankara.edu.tr/journal

Investigations on the Use of Kairomone and Pheromone Attractants for Control of *Thrips* Species (Thysanoptera: Thripidae) by Mass-trapping in Nectarine Orchards

Adalet HAZIR[a], Murat ÖLÇÜLÜ[b], Naim ÖZTÜRK[a]

[a]*Biological Control Research Institute, Adana, TURKEY*

[b]*Bayer Turkish Chemical Industry Trade Limited Company, Antalya, TURKEY*

ARTICLE INFO
Research Article
Corresponding Author: Adalet HAZIR, E-mail: adalet.hazir@tarim.gov.tr, Tel: +90 (322) 344 17 84/120
Received: 30 December 2018, Received in Revised Form: 29 March 2019, Accepted: 23 April 2019

AUTHORS ORCID ID:
(Adalet HAZIR:0000-0003-0749-2215), (Murat ÖLÇÜLÜ:0000-0003-3809-7752), (Naim ÖZTÜRK:0000-0003-3322-2868)

ABSTRACT
Thrips species (Thysanoptera: Thripidae) cause superficial, brown colored scars and discoloration called silvering on the surface of nectarine fruit which reduce market quality. In cases of high thrips populations, cracking and splitting of the fruit in accompany to superficial damage causes the fruit to be discarded. The study which was based on non-chemical control of thrips species was conducted in a commercial nectarine orchard in Tarsus county of Mersin province in 2013 and 2014. In the study, pest management effect of mass trapping by yellow colored sticky traps baited with semiochemical-kairomone and pheromone-were detected. Each semiochemical was tested in a particular plot. One baited trap per tree was hung at both kairomone and pheromone plots and one bait-free trap per tree at the control plot. The traps were all hung at the pink bud period and were recovered after harvest. The amount of thrips adult and larvae in the flower buds were checked 4-7 day intervals and the traps were checked weekly to count the individuals caught on traps. The results showed that the lowest number of thrips was detected in nectarine flowers in the kairomone plot and kairomone-baited traps captured the highest number of thrips adults. To the contrary, flowers taken from the control plot had the highest number of thrips and control traps captured the lowest number of thrips adults. The success of mass trapping by adding semiochemicals to sticky traps was evaluated by comparing fruit damage in baited and unbaited trap plots by observing 100 fruits on each of five replicate trees for 500 fruit total at each plot before harvest. The fruit damage was 9.0% and 9.8% in the kairomone plot and was 11.2% and 18.2% in the pheromone plot while it was 23.4% and 20.0% in the control plot in years 2013 and 2014 respectively. Mass trapping by baited traps for thrips control in nectarine orchards seems to be encouraging for integrated pest management especially when considering the easily occurring pesticide resistance of thrips species.

Keywords: Nectarine; Thrips control; Semiochemical; Lurem-tr; Thripline-ams

© Ankara Üniversitesi Ziraat Fakültesi

1. Introduction

The East Mediterranean Region of Turkey has a large potential of nectarine production for both domestic and external markets with 42226 tons of yearly production (Anonymous 2018). Numerous pest species like Thrips (Thysanoptera: Thripidae), Peach twig borer-*Anarsia lineatella* Zeller and Oriental peach moth-*Cydia molesta* (Busck.) (Lepidoptera: Gelechiidae), Aphids (Hemiptera: Aphididae), White peach scale-*Pseudaulacaspis pentagona* (Targ.-Tozz.) (Hemiptera: Diaspididae) put a strain on nectarine growing. Thrips species are considered a serious pest of nectarine. Thrips adults and larvae feed on nectarine flower organs, ovarium and fruitlet which cause brown scars on the fruit surface and also cause deformation of fruit (Gonzales et al 1994; Pearsall 2000; Pearsall & Myers 2000; Tommasini et al 2004; Sengonca et al 2006; Hazır & Ulusoy 2008; Atakan 2008). Thrips feeding on matured fruit causes discoloration damage called silvering (Gonzales et al 1994; Atakan 2008). Hazır et al (2011) notified that 3 flower thrips species among 12-*Frankliniella occidentalis* (Pergande), *Thrips tabaci* Lindemann and *Thrips major* Uzel (Thysanoptera: Thripidae)

DOI: 10.15832/ankutbd. 490532

were present in high numbers in nectarine flowers that cause scarred fruit in Mersin (Tarsus county) province of Turkey. According to the study of Tommasini et al (2004) the silvering damage was caused by *T. major, T. tabaci* and *F. occidentalis* on nectarine fruit in Nothern Italy. Similarly, according to Hazır & Ulusoy (2008), *F. occidentalis* and *T.major* caused silvering damage in Mersin, Turkey. Both types of damage are not desired by growers and consumers because of the decrease in value in domestic fruit marketing and during exportation. *F. occidentalis* is listed on the quarantine list of many countries including Turkey and regulated as a quarantine pest. Thrips management depends mostly on insecticide applications but the effect of insecticides is low due to some characteristics of thrips species such as the eggs are laid in the plant tissue, adults and nymphs are feeding in the interior parts of the flower and the pupa stage undergo in the soil.

As of 2011 there were no chemicals licensed against thrips on nectarines in Turkey. Some of the growers were using some pesticides *licensed* for *thrips* in other crops *like grape and strawberry* while some other growers were using any kind of pesticides that were licensed for nectarine pests other than thrips. Economic losses were being reported by technical experts because of unsuitable chemicals and ineffective control strategies (unpublished reports). Besides, thrips resistance to insecticides was a known fact (Herron & James 2007; Darnell-Crumpton et al 2018). This study was planned under these conditions to offer a control method as an alternative to chemical control. Effect of using sticky traps baited with pheromone and kairomone was tested for the purpose of breaking up the thrips populations in nectarine orchards in this study.

Adding pheromone and kairomone attractants to sticky traps are licensed for monitoring the thrips populations on protected crops in greenhouses in many countries. The attractants are slowly released from the dispenser and makes adult thrips more active. Adults appear from their shelters and are more attracted to sticky traps based on visual stimulant (color traps) and odor stimulant (pheromone or kairomone) (Anonymous 2019b and c). We planned to benefit this feature of attractants in thrips management in nectarine orchards by having thrips adults landing on traps instead of nectarine flowers and in this way decreasing fruit damage caused by thrips feeding. Kirk (2009) notified that aggregation pheromone of *F. occidentalis* increases capture of both male and female thrips on traps and were useful for early detection of thrips. Broughton (2009) tested monitoring efficacy of traps baited with Thripline-ams (*F. occidentalis* pheromone) and Lurem-Tr (kairomone) in a study in New Zealand nectarine orchards. The researcher notified that more thrips were captured on the traps combined with lures when compared with no-lure traps. Many other researchers tested and compared the capture capacity of baited and unbaited traps for the purpose of monitoring thrips adults earlier (Teulon et al 2008; Broughton & Harrison 2012; Sampson & Kirk 2013; Muvea et al 2014; Abdullah et al 2015) A few number of researchers tested the semiochemical baited traps for controlling thrips populations. Harbi et al (2013) detected that thrips populations in pepper greenhouse and Broughton et al (2015) notified that thrips in rose greenhouses can be successfully controlled by using sticky traps baited with semiochemicals. Within our study, the efficacy of mass-trapping by adding attractant (pheromone and kairomone) to yellow colored sticky traps was investigated in a nectarine orchard as a pest management strategy alternative to insecticide applications.

2. Material and Methods

2.1. Study site

Studies were conducted in a nectarine orchard located in Yenice/Tarsus county of Mersin province in East Mediterranean Region of Turkey in 2013 and 2014 during the nectarine growing season between pink bud and harvest period. The trial orchard was established with 'Early Sprite' nectarine cultivar having 4x5 m row spacing. The trees were 6 years old. A drip irrigation system was installed in the orchard. No insecticide had been applied in the study site and there weren't any weed species on the orchard base because of continued weed control by mowing.

2.2. Traps and semiochemicals

The sticky traps were yellow in color, self-adhesive, 10x25 cm in size, commercially supplied from Russell IPM (Anonymous 2019a). Traps were baited with two kinds of semiochemical attractants-pheromone and kairomone. Aggregation pheromone of *F. occidentalis* is composed of neryl (**S**)-2-methylbutanoate. Its' commercial name is Thripline-ams, producer company is Syngenta (Anonymous 2019b). Kairomone is an allelochemical attracting various thrips species like, *F. occidentalis, T. tabaci, T. major* and some other species. It is composed of plant volatiles derived from host plants, commercial name is Lurem-Tr, producer company is Koppert (Anonymous 2019c). The trial consisted of three characters [1.Mass-trapping by using yellow sticky traps baited with pheromone-Thripline-ams (PMT); 2.Mass-trapping by using yellow sticky traps baited with kairomone-Lurem Tr (KMT); 3.Mass-trapping by using attractant free yellow sticky traps-Control (CMT)]. All characters were replicated five times in a randomised block design. Each plot (block) consisted of 30 trees. Plots were seperated, having 50 meters between each other.

2.3. Method

The orchard was divided into 3 plots-kairomone (KMT), pheromone (PMT) and control (CMT). Five trees located in the middle of every trial plot were determined as replicates and 3 types of counts were conducted on these five trees: 1- Amount of thrips adult and larvae existed in the flower samples, 2- Amount of thrips adults caught on the traps, 3- Damage rates on the fruits.

2.3.1. Amount of thrips adults and larvae in nectarine flowers

One hundred randomly selected flower buds (20 buds from each of five replicate trees) were picked every 6-7 days during pink bud-petal fall period at each plot and brought into the laboratory in paper bags. A piece of cotton treated with ethyl acetate was placed in each paper bag to immobilize any thrips present in the flowers. Flower samples were knocked into a white plastic container to get the thrips inside. The hidden thrips were detected by tearing the flowers into pieces. The amount of thrips adult and larvae were recorded, then adults were saved in vials containing 8 parts 60% ethyl alcohol+1 part acetic acid+1 part glycerin for later identification (Hazır & Ulusoy 2012).

2.3.2. Amount of Thrips adults captured on traps

2.3.2.1. Mass trapping trial using yellow coloured sticky traps baited with Thripline-ams pheromone capsule

This trial was conducted in a plot consisted of 30 trees (PMT). A buffer zone of 15-20 meters was constituted by placing traps to the trees adjacent to the trial plot to prevent external infestations. One Thripline-ams pheromone capsule was attached to each yellow colored sticky trap. One baited trap per nectarine tree was placed at pink bud period on 29.01.2013 and 30.01.2014 at 1.5-2.0 m height towards the southwest-predominant wind direction. Pheromone lures were replaced with fresh ones monthly and the sticky traps on five sample trees (sample (replicate) trees were selected for counts) were replaced with clean ones weekly. The rest of the traps were replaced with clean ones when needed. Five traps/plot on the sample trees were brought to the laboratory weekly. The amount of thrips adults captured on traps was counted weekly in the laboratory under binocular microscope until harvest. Average amount of thrips per trap was calculated and recorded.

2.3.2.2. Mass trapping trial using yellow coloured sticky traps baited with Lurem-TR kairomone attractant

The method used in pheromone mass-trapping (PMT) plot was also used for kairomone mass-trapping (KMT) plot by hanging 1 Kairomone (Lurem-Tr) baited trap on each of the 30 trees on 30.01.2014. All counts were done in the same way as in the PMT plot.

2.3.2.3. Mass trapping trial using unbaited yellow coloured sticky traps

In the control plot (CMT), one unbaited trap was hanged on each tree. Thrips adults captured on traps on sample trees were counted weekly.

2.3.3. Evaluation of damage rate

Damage rate was determined by monitoring 500 matured fruits (100 fruits/tree x 5 trees). Fruits located in the 4 particular directions and in the center of each sample tree were randomly selected and monitored/inspected for thrips injury (russetting/silvering) a week before harvest on 25.04.2013 and 29.04.2014. Damage rate was classified by 0-3 scale (Atakan 2008). According to the scale, scar areas smaller than 0.5 cm^2 were called light damage (scale 1), scar areas between 0.5-2.0 cm^2 were called medium damage (scale 2) and larger than 2.0 cm^2 were called severe damage (scale 3).

Statistical analysis was performed by using SPSS statistics package software. Variance analysis was performed after logarithmic and arcsin transformation was done to the data of the trial and the difference between treatments was evaluated by using the Tukey multiple comparison test. T-test was used for paired comparisons.

3. Results and Discussion

3.1. Amount of thrips adults and larvae in nectarine flowers

The flowering period started on the last days of January in both years. Amount of thrips in the flower samples in 2013 and 2014 is shown in Table 1. As seen in the table, the highest number of thrips adult/larvae in the flower samples at petal fall in both years were obtained from the CMT plot where unbaited traps were used (Table 1). The lowest number of thrips were detected in the flower buds taken from KMT plot at petal fall in both years. The odor of semiochemicals activate thrips adults and direct them towards an object like colored sticky traps that attract attention. According to previous studies in the world, adding semiochemicals (pheromone or kairomone) to sticky traps attracts thrips adults to traps (Broughton 2009; Kirk 2009; Anonymous 2019b; c). While capture of thrips adults on traps increases, the amount of thrips landing on and feed in flower buds reduces. This phenomena results in less fruit damage. Results of two trial years showed that mass trapping by using baited traps reduced thrips existence in flowers when compared with control. Amount of thrips in flowers were the lowest in the KMT plot in both years which lead to the lowest fruit damage at harvest. The highest damage was noted in the CMT plot where the flower samples consisted of the highest amount of thrips.

Table 1- Amount of thrips adults and larvae in nectarine flowers in 2013 and 2014

Sampling time	*2013*			*2014*		
	Kairomone (KMT)	*Pheromone (PMT)*	*Control (CMT)*	*Kairomone (KMT)*	*Pheromone (PMT)*	*Control (CMT)*
- Beginning of flowering	0	0	0	8 a	0	0
- Full bloom	6 a*	3 a	10 a	7 a	11 a	16 a
- Petal fall	3 a+6 l**	4 a+8 l	8 a+16 l	11 a+3 l	26 a+6 l	29a+9 l

*a, adult; **l, larvae

Thrips adults collected from flowers were identified into species by the expert Prof. Dr. Ekrem ATAKAN (Çukurova University, Agriculture Faculty, Plant Protection Department). Four thrips species-*T. major, F. occidentalis, T. tabaci* and *Haplothrips subtilissimus*-were identified in the nectarine flowers. The incidence percantages of *T. major, F. occidentalis* and *Haplothrips subtilissimus* in flower samples were 75.9%; 20.7%; 3.4% respectively in 2013 and 52.6% for *T. major*; 36.8% for *F. occidentalis;* 10.5% for *T. tabaci* in 2014 during petal fall period.

3.2. Amount of thrips adults captured on traps

3.2.1. Results of the first year (2013)

Thrips population peaked three times in 2013. The first peak flight was seen at petal fall on 12 March 2013 simultaneously with increases in the average air temperature (15.8 °C). The second and the greatest peak was on 02 May 2013 at harvest period when the air temperature peaked to 25.2 °C and the last peak flight was seen on 23 May (Table 2). The amount of thrips adults captured on traps at the petal fall period on 12 March 2013 was 390.4±55.0 adults/trap on the KMT traps while it was 41.8±9.3 and 22.0±2.6 in the PMT and the CMT traps respectively. Amount of thrips on traps increased and peaked on 02 May 2013 in all plots. The highest capture was on the kairomone plot (KMT) with 1196.8±245.7 adults/trap while it was 270.0±27.0 and 240.0±56.9 adults on the PMT and CMT plots respectively. According to statistical analysis, PMT and CMT were placed in the same group (a) on 12 March, 2 May and 23 May while KMT and CMT were in seperate groups on all dates (Table 2). The amount of thrips captured on the KMT trap was 5 times more than on CMT traps on 2nd May (Table 2). According to the total number of thrips captured on traps between flower bud and fruit harvest, it is seen that 9 times more thrips adults were captured on KMT traps (7375.4) in comparison to CMT traps (813.1). Number of adults captured on PMT trap (1230.1) was 1.5 times more than CMT traps.

Table 2- Amount of thrips captured on traps in trial plots in 2013 and 2014 (means of 5 traps)

Date	*Amount of thrips adults on traps (2013)*				*Date*	*Amount of thrips adults on traps (2014)*			
	Kairomone (KMT)	*Control (CMT)*	*df*	*P value*		*Kairomone (KMT)*	*Control (CMT)*	*df*	*P value*
*12 March	390.4±55.0a***	22.0±2.6b	8	0.0001	*04 March	455.8±97.2a	64.6±5.8b	8	0.004
25 April	884.6±161.2a	55.2±8.9b	8	0.001	22 April	3564.0±362.6a	315.2±92.3b	8	0.0001
**02 May	1196.8±245.7a	240.0±56.9b	8	0.005	**07 May	1895.2±235.7a	316.2±36.4b	8	0.0001
23 May	855.5±42.7a	102.0±13.9b	8	0.0001	29 May	492.8±67.4a	38.0±4.4b	8	0.0001
Date	*Pheromone (PMT)*	*Control (CMT)*	*df*	*P value*	*Date*	*Pheromone (PMT)*	*Control (CMT)*	*df*	*P value*
12 March	41.8±9.3a	22.0±2.6a	8	0.074	04 March	148.2±7.5a	64.6±5.8b	8	0.0001
25 April	196.8±24.9a	55.2±8.9b	8	0.001	22 April	672.8±82.7a	315.2±92.3b	8	0.0001
02 May	270.0±27.0a	240.0±56.9a	8	0.647	07 May	672.8±62.2a	316.2±36.4b	8	0.001
23 May	180.0±64.5a	102.0±13.9a	8	0.090	29 May	105.0±22.7a	38.0±4.4a	8	0.045

*, Petal fall; **, harvest; ***, data are means of 5 replicate per treatment; Means followed by the same letters do not differ significantly (P≤0.05); Independent samples t test has been performed for comparing the kairomone/control and pheromone/control plots separately. Logarithmic transformation has been done before performing analysis

3.2.2. Results of the second year (2014)

Thrips population peaked four times in 2014. The first peak was seen during petal fall period in all plots when the air temperature was 13 °C. Two more population peaks occured synchronous with increases in temperature. The last peak was on 22 April 2014 (2 weeks before harvest) when the temperature increased to 18 °C (Table 2). The highest amount of thrips at the end of blooming period (petal fall) on 04.03.2014 was captured on kairomone traps. Average thrips density on the kairomone traps was 455.8±97.2 while it was 148.2±7.5 on the pheromone and 64.6±5.8 on the control traps on 04.03.2014. According to statistical analysis, KMT and CMT placed in seperate groups-CMT (group a) and KMT (group b) (Table 2). When compared with control traps, kairomone traps captured 7 times and pheromone traps captured 2.3 times more thrips adults. The highest number of thrips adults captured on the kairomone traps was 3564.0±362.6 adults on 22.04.2014 while it was 672.8±82.7 and 315.2±92.3 on pheromone and control traps respectively. According to statistical analysis, the differences between treatments (KMT-CMT and PMT-CMT) were significant at 5% level (P≤0.05). According to Tukey multible comparison test, KMT and CMT; PMT and CMT were placed in seperate groups (Table 2). When compared with control traps, it was seen that kairomone traps captured 11.3 and pheromone traps captured 2.1 times more thrips than control traps on 22 April (Table 2). The total thrips density captured on kairomone traps from pink bud stage till harvest was 8.3 times more than control traps. Total amount of thrips on pheromone traps was 2.3 times more than control traps.

Findings of some previous studies confirm our results. Harbi et al (2013) recorded that number of thrips adults trapped on traps baited with kairomone were higher than unbaited traps in a study conducted in a pepper greenhouse in Tunisia. Broughton & Harrison (2012) conducted a study in nectarine orchards in West Australia and tested capture efficacy of sticky traps baited with pheromone (Thripline-ams) and kairomone (Lurem Tr). Researchers notified that traps baited with lures attracted and captured more thrips adults than no lure traps and adding lures enhances the capture efficacy of traps. Similarly, Broughton et al (2015) recorded that in a greenhouse of roses, 1.2-4.0 times more F. occidentalis were caught on traps baited with aggregation pheromone and kairomone compared to unbaited traps. Muvea et al (2014) conducted a study in a bean field in Kenya and determined that attaching Lurem Tr kairomone lure to sticky traps caused significant increases in capture rate of all thrips species. They recorded negative correlation between trap captures and direct plant sampling.

Likewise in the study conducted by the authors of this article in Turkey, capture of thrips on kairomone traps was the highest while thrips existence in the flower samplings was the lowest in the KMT plot. Due to low thrips density in the flower buds based on high thrips capture on traps, the damage rate on the nectarine fruit in this plot was the lowest.

3.3. Damage rate on fruit

3.3.1. Results of the first year (2013)

In order to score the rate of thrips damage, observations on fruits were done on sample trees. The percentage and intensity of damage is shown in Table 3. Table 3 indicates that fruit damage were mostly light (scale 1) in kairomone (KMT) and pheromone (PMT) plots while most damage was medium grade (scale 2) in the control (CMT) plot in 2013. The highest damage was noted in control plot where 23.4% of the fruit were damaged. The damage was 11.2% and 9.0% in PMT and KMT plots respectively. Independent samples t-test was carried out to the data of damaged fruit. The difference between treatments appeared significant at 5% Alpha level ($P \leq 0.05$). According to the t-test shown in Table 3, treatments were placed in seperate groups when compared to control (kairomone group b/control group a and pheromone group b/control group a.

Table 3- Rates (%) and intensity of the damage in means of 0-3 scale in 2013 and 2014

Damage rate and intensity (%)	*2013*					*2014*				
	Treatments			*df*	*P value*	Treatments			*df*	*P value*
	*CMT	*PMT	*KMT			*CMT	*PMT	*KMT		
**Scale 1	***8.8	***6.2	***5.0	-	-	10.6	8.0	4.6	-	-
**Scale 2	11.8	2.8	3.4	-	-	8.4	6.4	3.8	-	-
**Scale 3	2.8	2.2	0.6	-	-	1.2	0.6	0.4	-	-
Total	23.4a		9.0b	8	0.0001	20.2a		8.8b	8	0.0001
	23.4a	11.2b		8	0.020	20.2a	15.0b		8	0.0001

*CMT, Control mass trapping; PMT, Pheromone mass trapping; KMT, Kairomone mass trapping; **Scale 1, light damage; Scale 2, medium damage; Scale 3, severe damage; ***, data, are percentage of damaged fruits; percentages followed by the same letters do not differ significantly ($P \leq 0.05$); Independent samples t test has been performed for comparing kairomone/control and pheromone/control plots separately. Arcsin transformation has been done before performing analysis

The aim of this study is to draw adults away from flowers and pull them towards baited traps by using olfactory and visual sitimulants. Capturing maximum amount of thrips on the traps especially during full bloom, petal fall and pre-harvest period would result in decreased amount of damaged fruit. To understand the relationship between the fruit damage and trap capture, Table 2 and Table 3 are evaluated together. According to Table 3, the amount of damaged fruit in 2013 was the lowest (9.0%) in the KMT plot (Table 3) where total trap capture throughout blooming period was the highest (477.2 thrips/trap) (Table 2) and similarly damage was the highest (23.4%) in the CMT plot (Table 3) where trap capture attracted to yellow traps baited with kairomone (Lurem Tr) instead of nectarine flowers in the KMT plot which resulted in lower fruit damage.

Obtaining lower number of damaged fruit in kairomone and pheromone plots when compared with control plot is a promising and encouraging result for the applicability of mass trapping of thrips adults by using baited colored traps for thrips management in nectarine orchards.

3.3.2. Results of the second year (2014)

Number of damaged and undamaged fruit in the trial area in 2014 is shown in Table 3. It is seen in the table that thrips damage was 'light'(Scale 1) in all plots. The highest damage was in the control plot where the damaged fruit rate was 20.2%. It was followed by pheromone and kairomone plots where 15.0% and 8.8% of the fruit was damaged respectively (Table 3). According to statistical tests, the difference between treatments was significant at Alpha 5% level. PMT and CMT were placed in different groups (PMT group b-CMT group a). Similarly KMT and CMT were placed in different groups (Table 3). To understand the interaction between trap capture and damage rate, table 2 and 3 should be evaluated together. The highest trap capture was seen in the kairomone plot on all dates of checking. This was followed by pheromone and the lowest capture was seen in the control plot (Table 2). According to the correlation between trap capture and fruit damage, it was seen that number of damaged fruit was the lowest in kairomone plot where trap capture was the highest and damage was the highest in the plot where thrips capture was the lowest (control plot). This showed that thrips adults were attracted to kairomone baited traps instead of nectarine flowers. In other words, kairomone bait attracted thrips adults by means of the specific odor and adults prefered traps instead of flowers to land on-which in turn caused less fruit damage.

Findings of a previous study confirms our results. Sampson & Kirk (2013) found out that, in semi-protected strawberry crops, mass trapping of F. occidentalis by using blue sticky roller traps reduced adult thrips numbers per flower by 61% and fruit bronzing by 55%. As to the researchers, the addition of the F. occidentalis aggregation pheromone, neryl (**S**)-2-methylbutanoate to the traps doubled trap efficacy, reduced number of thrips adults per flower by 73% and fruit bronzing by 68%.

The results of the two years study in nectarine orchard in Tarsus/Turkey revealed that fruit damage was lower in the KMT and PMT plots when compared to the control plot by attracting adults towards sticky traps using visual and olfactory cues and by this way taking the adults away from the flowers. The kairomone baited traps caught 8 to 16 times more thrips than control traps throughout the trial, starting from blooming period until harvest. The higher capture of kairomone baited traps is due to its' feature not being specific to any particular thrips species but attracting several species like *F. occidentalis*, *T. tabaci*, *Thrips imaginalis* (Broughton & Harrison 2012), *T. major* and etc. In the study, four thrips species appeared together in the nectarine flowers in 2013 and 2014. Therefore, an effective thrips management could be achieved in the plot where Lurem-Tr kairomone attractant was used.

Thripline-ams pheromone attractant is an aggregation pheromone of *F. occidentalis*, and could attract only this species. It is obvious that the higher fruit damage in pheromone plot is due to attracting only one specific thrips species- *F. occidentalis.* In the study area four thrips species responsible of the fruit damage were detected in flowers. For this reason Thripline-ams could be limitedly effective on thrips management in nectarine orchard.

4. Conclusions

Thrips management depends mostly on insecticide applications but the effect of insecticides is low due to some characteristics of thrips species such as the eggs are laid in the plant tissue, adults and nymphs are feeding in the interior parts of the flower and the pupa stage undergo in the soil. Thrips resistance to insecticides is another problem. For a proper thrips management, an alternative method instead of insecticide usage should be implemented.

In this study, the effect of mass-trapping of thrips adults with sticky traps baited with attractants was tested for thrips control in nectarine orchards. Two years' output of the study revealed that kairomone baited traps are much more successful than control traps in mass trapping of thrips species. Based on these results, the usage of kairomone baited traps for thrips control in nectarine orchards seems to be encouraging for integrated pest management. Thrips pheromone-Thripline-ams is also a promising attractant that can be used for thrips control in the orchards where predominant thrips species is *F. occidentalis*. This study revealed that mass trapping of thrips species by using semiochemicals would be an alternative control strategy when easily developing pesticide resistance of thrips species is considered. Besides, usage of baited traps could be a supplementary agent that can help to increase the success of insecticides in commercial orchards.

It is a known fact that colored traps are attractive for natural enemies and has a negative effect on their population (Atakan et al 2016). Kairomone added traps were found out more attractive to natural enemies than pheromone added traps and bait free traps during this study. But, it is another known fact that insecticides also knock down most of natural enemy populations. For this reason it would be wrong to pass judgement on this issue without a comparison study being conducted on the effect of sticky traps and the effect of insecticides on natural enemies. For all that, using semiochemical baited traps are recommended for thrips control in nectarine orchards and should be in hand as a tool for management strategy.

Acknowledgements

Many thanks to Prof. Dr. Ekrem ATAKAN (Çukurova University, Agriculture Faculty, Plant Protection Department, Adana-TURKEY) for his contribution on thrips species identification.

Abbreviations and Symbols	
PMT	Pheromone mass trapping
KMT	Kairomone mass trapping
CMT	Control mass trapping

References

Abdullah Z S, Greenfield B P J, Ficken K J, Taylor J W D, Wood M & Butt T M (2015). A new attractant for monitoring western flower thrips, Frankliniella occidentalis in protected crops. *Springerplus* 4: 89

Anonymous (2018). Turkey Statistics Corporation

Anonymous (2019a). Fact sheet. Impact board yellow. Retrieved in 2018 from http://russellipm-agriculture.com/impact-board-yellow

Anonymous (2019b). Thripline *Frankliniella occidentalis*. Retrieved in 2019 from http://www.biolineagrosciences.com/products/thripline

Anonymous (2019c). Lurem-TR. Thrips attractant kairomone Thripidae. Retrieved in 2019 from https://www.koppert.com/lurem-tr

Atakan E (2008). Population fluctuations of two thrips (Thysanoptera) species and the thrips damage associated with some temperate fruits in Adana province, Turkey. *Turkish Journal of Entomology* 32(4): 255-271

Atakan E, Pehlivan S & Satar S (2016). Response of some beneficial insect species to colored sticky traps in citrus. *Turkish Journal of Entomology* 40(4): 385-396

Broughton S (2009). Evaluation of colour and pheromones for monitoring thrips (Thysanoptera: Thripidae) in pome and stone fruit. *IXth International Symposium on Thysanoptera and Tospoviruses*. 31August-4 September 2009, Australia. *Journal of Insect Science* Vol. 10 (141): 6

Broughton S & Harrison J (2012). Evaluation of monitoring methods for thrips and the effect of trap colour and semiochemicals on sticky trap capture of thrips (Thysanoptera) and beneficial insects (Syrphidae, Hemerobiidae) in deciduous fruit trees in Western Australia. C*rop Protection* 42: 156-163

Broughton S, Cousins D A & Rahman T (2015). Evaluation of semiochemicals for their potential application in mass trapping of *Frankliniella occidentalis* (Pergande) in roses. *Crop Protection* 67: 130-135

Darnell-Crumpton C, Catchot A, Cook D R, Gore J, Dodds D M, Morsello S C & Musser F (2018). Neonicotinoid insecticide resistance in tobacco Thrips (Thysanoptera: Thripidae) of Mississippi. *Journal of Economic Entomology* 111(6): 2824-2830

Gonzales E, Alvaro M, Berlanga E, Serrano A & de la Rosa A (1994). Damage to nectarines caused by thrips in the Guadalquivir Valley. *Boletin de Sanidad Vegetal, Plagas* 20(1): 229-241

Harbi A, Elimem M & Chermiti B (2013). Use of a synthetic kairomone to control *Frankliniella occidentalis* Pergande (Thysanoptera; Thripidae) in protected pepper crops in Tunisia. *The African Journal of Plant Science and Biotechnology* 7(1): 42-47

Hazır A & Ulusoy M R (2008). Studies on determination of pests, predators and parasitoits, population dynamics of major pests, and the effects of various pesticides on *Chilocorus bipustulatus* l. (Coleoptera: Coccinellidae) in peach and nectarine orchards in the East Mediterranean Region. PhD Thesis, Cukurova University, Turkey, 145 pp

Hazır A & Ulusoy M R (2012). Population fluctuation of Thrips species (Thysanoptera: Thripidae) in nectarine orchards and damage levels in East Mediterranean Region of Turkey. *Journal of Entomological Research Society* 14(1): 41-52

Hazır A, Ulusoy M R & Atakan E (2011). Studies on determination of Thysanoptera species associated with nectarines and their damage in Adana and Mersin provinces, Türkiye. *Turkish Journal of Entomology* 35(1): 133-144

Herron G A & James T M (2007). Insecticide resistance in Australian populations of western flower thrips, *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae). *General and Applied Entomology* Vol. 36: 1-6

Kirk W D J & Hamilton J G C (2009). The aggregation pheromones of thrips. *IXth International Symposium on Thysanoptera and Tospoviruses*. 31August-4 September 2009, Australia. *Journal of Insect Science* Vol. 10(141): 19-20

Muvea A M, Waiganjo M M, Kutima H L, Osiemo Z, Nyasani J O & Subramanian S (2014). Attraction of pest thrips (Thysanoptera: Thripidae) infesting French beans to coloured sticky traps with Lurem-TR and its utility for monitoring thrips populations. *International Journal of Tropical Insect Science* 34(3): 197-206

Pearsall I A (2000). Damage to nectarines by the western flower thrips (Thysanoptera: Thripidae) in the Interior of British Columbia, Canada. *Journal of Economic Entomology* 93(4): 1207-1215

Pearsall I A & Myers J H (2000). Population dynamics of Western flower thrips (Thysanoptera: Thripidae) in nectarine orchards in British Columbia. *Journal of Economic Entomology* 93(2): 264-275

Sampson A & Kirk W D J (2013). Can mass trapping reduce Thrips damage and is it economically viable? management of the western flower Thrips in strawberry. *PLoS ONE* 8(11): e80787

Sengonca C, Blaeser P, Ozden O & Kersting U (2006). Occurence of thrips (Thysanoptera) infestation on nectarines and its importance to fruit damage in North Cyprus. *Journal of Plant Diseases and Protection* 113(3): 128-134

Teulon D A J, Nielsen M C, de Kogel W J, van Tol R W H M & Davidson M M (2008). A new lure for Thrips major. New Zealand Plant Protection 61: 386. https://www.researchgate.net/publication/266375549

Tommasini M G, Cravedi P, Mazzoni E & Burgio G (2004). The damage of thrips on nectarine: sampling methods of populations and injury levels. *Bulletin OILB-SROP* 27(5): 35-47