EFFICACY OF IPM, MASS TRAPPING AND CHEMICAL CONTROL IN THE SUPPRESSING OF MEDITERRANEAN FRUIT FLY, [*CERATITIS CAPITATA* (WIEDEMANN) (DIPTERA: TEPHRITIDAE)] IN CITRUS

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Abstract. The management of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) in Turkey is mainly through chemical control. In this study, the effectiveness of the integrated pest management (IPM), mass trapping and chemical control were compared in an orange orchard in Tarsus (Mersin) during 2015 and 2016. The IPM program was based on the use of the synthetic food attractant lure Biolure, paired with sanitation of infected fruits and chemical control if necessary. In mass trapping plots the female targeted attractant lure Biolure and the male targeted sex attractant lure Trimedlure were used. Chemical control was based on bait treatments with Spinosad. The efficiency of the applications was evaluated according to the rate of infected fruits during harvest. The highest number of flies was detected in the Control plot as 404 flies/trap/week in 2015 and in Chemical Control plot as 429 flies/trap/week in 2016. No statistical difference was found between the applications regarding the number of male flies weekly captured and number of infected fruits. However, it was determined that the ratio of infected fruits in the IPM plot was lower than that of other plots (1.57% in 2015 and 0.89% in 2016) at harvest, followed by Biolure, Trimedlure and Spinosad, respectively. It was concluded that IPM, which included the application of several methods, was the most effective control practice for *C. capitata.*
Keywords: *Ceratitis capitata, food attractant, IPM, lure, sanitation, spinosad*

Introduction

The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae) is a significant quarantine pest. It is spread out over a wide area around the world due to its high tolerance to climatic changes compared to many other fruit fly species. Worldwide, *C. capitata* has over 579 fruits and vegetables as hosts (Liquido et al., 2017). It causes economic damage to many fruit species in Turkey, first and foremost to citrus fruits. The pest completes its generation on these hosts before the citrus fruits mature, therefore, pest population is higher on citrus. Yield loss can reach 100% if the necessary pest control measures are not taken (Thomas et al., 2001; Umeh et al., 2004). The economic consequences of its presence include not only direct losses in yield and increased control costs, but also indirect damage, which is usually higher, such as loss of export markets, severe restriction of exports of most commercial fruits as a result of quarantine laws, and the cost of maintaining facilities for fruit treatment and eradication (Radonjić, 2013). There are various control methods used for this pest, including chemical control (bait application, foliar application), biotechnological control (mass trapping) and the release of sterile insects, which is applied in some countries (Martinez-Ferrer et al., 2010; Anonymous, 2018; Gëzhilli et al., 2018). Bait application is recommended in Turkey as it allows the maintenance of natural balance, protects human and environmental health and enables the reduction of the number of insecticides used in chemical control. Due to the limits of chemical control, alternative solutions that do not

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leave pesticide residues have been sought after and trials based on mass trapping have been conducted. In Turkey, the use of biotechnological control techniques has been continuous since the 1970s. The effect of different attractants or trap and attractant combinations on the pest has been studied (Zümreoğlu, 1990; Epsky et al., 1999; Başpınar et al., 2011). Various studies, in which male and female attractants were used, have been performed in *C. capitata* mass trapping (Heath et al., 2004; Navarro-Llopis et al., 2008; Satar and Tireng, 2016). Trimedlure has been reported as the most effective and the most used male-specific attractant for detection and suppressing *C. capitata* (Hill, 1987; Tan et al., 2014). Heath et al. (1997) developed a synthetic food lure system that attracts both females and males (Biolure, 3-component fruit fly attractant). This attractant has been commonly used in many studies in order to monitor and suppress the pest population (Epsky et al., 1999; Cohen and Yuval, 2000; Papadopoulos et al., 2001; Broughton and De Lima, 2002; McQuate et al., 2005; Navarro Llopis et al., 2008; Martinez-Ferrer et al., 2012). Although it has increased over the years, only a limited number of producers apply the mass trapping method for *C. capitata* control in Turkey. While some producers think this control method is not sufficient for suppressing the pest, others think the method is difficult to apply. For this reason, they prefer chemical control, which is easier and cheaper but requires repetition at certain intervals. However, problems such as labour and loss of time have also been reported in the application of this method, particularly in large orchards. The damage rate varies between 8-15% in mass trapping applications performed on citrus orchards (Satar and Tireng, 2016; Demirel and Akyol, 2017; Yayla and Satar, 2017). It has also been reported that successful results were obtained with the application of mass trapping in an integrated pest management program and that 0.5% damage rate was achieved as a result of cultural control and other methods together until harvest (Martinez-Ferrer et al., 2012). The objective of this study was to compare the effectiveness of male-targeted and female-targeted *C. capitata* attractants, IPM and also chemical control against *C. capitata*.

Materials and methods

Groves and trapping scheme

The trial was conducted on a citrus orchard located in the eastern Mediterranean region of Turkey (Tarsus/Mersin). The orchard (36°55'04.90" N, 34°56'06.12" E) was a 7,5 ha area, drip irrigated and 15 m above sea level. It was planted with orange trees (*Citrus sinensis* var. Washington navel) that were 20 years old. Up until the experiment began, Spinosad was applied as bait (1 L/10 L-with 10 day intervals) in the orchard against *C. capitata*. The orchard was surrounded by a mandarin orchard on the north, a factory on the east and an area of field crops on the west and south. It was divided into six plots, with each plot being 1 ha for different treatments. All plots were besides each other at one edge of the orchard whereas only the control plot was at the other edge. Two rows were kept between the plots as barriers. To evaluate the efficacy of the applications, a randomized block design with four replicates was used. The following treatments were compared: 1) Chemical control with Success 0.24 CB bait application (CC), 2) Mass trapping with male attractant Trimedlure (MMT), 3) Mass trapping with female attractant Biolure, (3 component female-biased attractant - ammonium acetate, trimethylamine and putrescine) (FMT), 4) Integrated pest management program (Mass trapping with female attractant Biolure + sanitation by eliminating the punctured dropped fruits weekly + bait application if necessary) (IPM), and 5) Untreated control (C) (*Table 1*).

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The insecticide treatments on the chemical control plot were performed according to the bait application method (Anonymous, 2015). Spinosad (1 L/10 L) was applied as insecticide at 10-day intervals and 150 ml pesticide-water mixture was used per tree. The remaining trees in the orchard were also treated with Spinosad. In the first mass trapping plot (MMT), experiments were performed using Eostrap® invaginada traps (Sanidad Agricola Econex, Santomera, Murcia, Spain) baited with %95 Trimedlure (formulated in a polymeric plug-type dispenser) (Sanidad Agricola Econex, Santomera, Murcia, Spain) and 2.2- dichlorovinyl dimethyl phosphate (DDVP) tablet (Sanidad Agricola Econex, Santomera, Murcia, Spain) as insecticide. A trap density of 20 traps/ha was applied for capturing adult males in both years. In the second mass trapping plot (FMT), Tephri-traps baited with synthetic female-targeted food attractant lure marketed as BioLure®UnipakTM (AgriSense-BCS Ltd., Pontypridd, South Wales, UK) and the insecticide dichlorvos (DDVP strips) (AgriSense-BCS Ltd., Pontypridd, South Wales, UK) were used (*Fig. 1*). A trap density of 50 traps/ha was applied for capturing adult females and males in both years. The adults captured in the traps were counted and recorded separately as females and males. In IPM plot the program was designed identically to the FMT plot. All the infected fallen fruits from all trees on this plot were collected once a week and destroyed. In addition, Spinosad was treated as bait when it was necessary.

Table 1. *Treatment regimes during the study period*

No	Trials		Treatments
1	Chemical control	CC	Spinosad bait application - 1L/10L
2	Mass trapping	MMT	Trimedlure male attractant - 20 traps/ha
3	Mass trapping	FMT	Biolure female attractant - 50 traps/ha
4	Integrated pest management	IPM	Mass trapping with Biolure + sanitation by eliminating the punctured dropped fruits + bait application if necessary
5	Untreated control	C	-

Figure 1. *Trapping devices used in the field trials: a, b: Tephti trap with Biolure, c, d: Eostrap with Trimedlure*

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Treatments and population monitoring

Ceratitis capitata population was monitored by counting the males captured in 10 Jackson traps with Trimedlure as the attractant, hung on each tree in the middle row of all the plots. The traps were checked once a week. In the plots with Biolure use, the number of females was determined by counting the females captured in 10 traps which were marked at the beginning of the study. In all plots, mass traps and monitoring traps were hung in 29 August 2015 and 30 August 2016. They were hung at a height of 1.5-2.0 m from the ground in a shaded part of the canopy facing the south-east and were homogeneously distributed throughout the plots. The pheromone dispensers in the Eostrap traps were changed once every 90 days, while the pheromone dispensers in the Biolure traps were changed once every 120 days. Furthermore, the pheromone dispensers in the monitoring traps were changed once every 6 weeks.

Fruit damage assessment

Ten trees were chosen randomly from the middle row of all plots. The fallen fruits from these trees were collected every week, recorded as healthy or infected and removed from the orchard. The main assessment was performed during harvest; 100 fruits were controlled randomly from all sides of these trees and recorded as healthy or infected. The damage ratios (%) were calculated from the results of both counts.

Statistical analysis

The effect of applications on the male captures and fruit damage was analysed using a one-way Anova, where the applications were used as independent variables and “number of males captured” and “total number of infected fruits” were used as dependent variables. Means were separated by Tukey’s honestly significant difference (HSD) test at $P<0.05$. All analysis were performed using the Microsoft statistics program SPSS 25.0. Damage ratio (%) was determined from the number of infected fruits recorded weekly and during harvest. The impacts of the IPM, mass trapping and bait treatments on the pest population were measured according to the Abbot formula [Effectiveness % = (Infected fruit % in Control - Infected fruit % in Trials/ Infected fruit % in Control) x 100] by the infected fruit reduction between the plots (Abbott, 1925). Results were expressed as percentage of damaged fruits.

Meteorological data were obtained from ‘Tarsus Soil and Water Sources Research Center’ located 2 km away from the tested orchard.

Results

Ceratitis capitata flight activity

The number of *C. capitata* males captured in Jackson traps on the CC plot were low in number throughout September for all applications in 2015 and 2016. In 2015, pest population started to increase as of October and reached the highest number on the second half of the month (22.10.2015). Pest population was determined as 369 flies/trap/week averagely for this period, remained within similar levels from the end of October to the mid of November and showed a decreasing trend in the following counts until harvest. The average number of males was determined as 124.64 adults/trap for this plot throughout the season. The first Spinosad treatment in this plot was carried out on 28 September 2015. Treatments continued at 10-day intervals, and a total of 8 treatments

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were performed until the harvest on 17 December 2015. In 2016, pest population peaked at the end of October (31.10.2016) with averagely 429 flies/trap/week. Throughout the season, the average number of males for this plot was 122.79 adults/trap (*Table 2*). The first insecticide was treated on 03 October 2016, and a total of 7 treatments were performed until harvest on 22 December 2016. In the MMT and FMT plots, the highest number of adults in 2015 were recorded at the end of October as averagely 325 and 256 flies/trap/week, respectively. Pest population showed a decreasing trend until harvest (*Fig. 2*). The average number of males on these plots throughout the season was determined as 120.14 and 104.14 adults/trap, respectively (*Table 2*). On the IPM plot, pest population started to increase after the second half of October, and the highest number of adults was counted as 383 flies/trap/week on average on 29 October 2015. In order to increase the efficiency of mass trapping, Spinosad bait was applied just after this date. The pest population immediately decreased after the application. The average number of males on this plot throughout the season was determined as 109.29 adults/trap. The number of males captured in the traps was highest in the Control plot. The highest number of adults was again determined at the end of October (29.10.2015) as averagely 404 flies/trap/week. The number of males on this plot throughout the season was averagely 141.71 adults/trap (*Table 2*).

Table 2. *Average number of male Ceratitis capitata captured and infected fruits under different application regimes during 2015 and 2016*

Trials	Mean male medflies captured/Trap±SE (Min. -Max.)		Infected fruit number±SE (Min. -Max.)	
	2015	2016	2015	2016
Chemical Control	124.64±28.15a* (25-369)	122.79±31.86a (34-429)	11.86±2.23A* (0-26)	9.14±2.11A (0-25)
Mass Trapping (Male)	120.14±25.12a (28-325)	110.14±31.07a (12-383)	8.36±1.71A (0-19)	7.07±1.64A (0-18)
Mass Trapping (Female)	104.14±21.39a (17-256)	114.79±34.52a (21-397)	4.21±0.90A (0-9)	3.71±1.00A (0-12)
Integrated Pest Management	109.29±3.83a (14-383)	111.86±23.33a (22-286)	3.29±0.58A (0-7)	3.07±0.70A (0-6)
Control	141.71±35.79a (33-404)	137.57±25.94a (31-356)	26.21±4.05B (0-43)	23.57±3.74B (0-44)

*Means followed by the same letter within a column are not significantly different by Tukey’s multiple comparison test where P<0.05

Considering all applications, pest population was determined to be high particularly from the second week of October until the mid of November. Although the highest number of adults was counted in the Control plot, no statistical difference was determined among the applications ($F=0.273$; $df=4, 65$; $P = 0.894$). In 2016, the highest number of adults was captured on 31 October 2016, with averagely 429, 383, 397, 286 flies/trap/week for the CC, MMT, FMT, IPM plots, respectively. In the Control plot, the highest number of adults was determined one week before the other plots on 24 October 2016 with an average of 356 flies/trap/week. Throughout the season, the average number of males were determined as 122.79, 110.14, 114.79, 111.87, and 137.57 adults/trap in the CC, MMT, FMT, IPM, and Control plots, respectively (*Table 2*).

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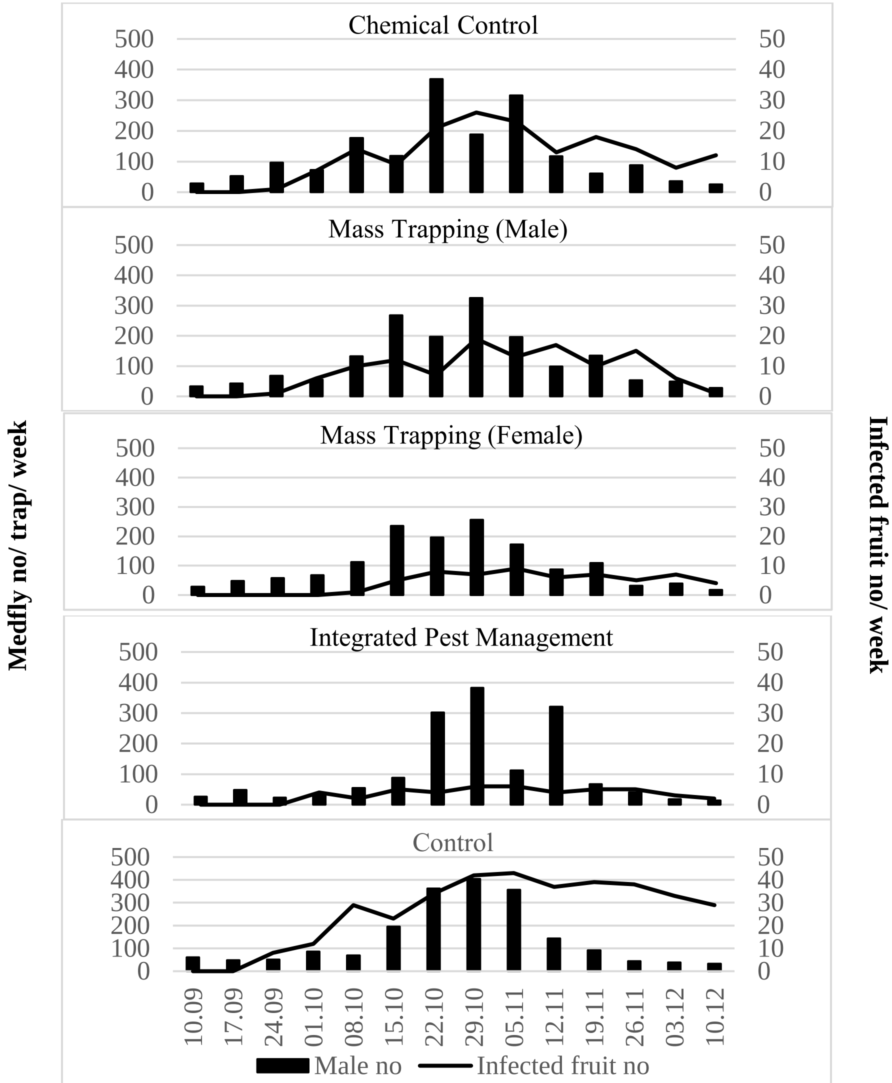

***Figure 2.** The number of males captured in the Jackson traps and the infected fruits in the plots comparing different methods against Ceratitis capitata in Tarsus (Mersin) in 2015*

In 2016, until harvest, the adults continued to be captured in the traps on all the plots (*Fig. 3*). No insecticides were treated on the IPM plot this year. The highest number of males was determined in the Control plot, however, no statistical difference was determined among the applications this year (F=0.138; df=4, 65; P=0.968).

On the FMT plot, the number of females was higher than the males. In 2015, 4.312 and 4.925 females were captured from the FMT and IPM plots, respectively. Accordingly, the rate of males on the FMT plot was determined as 25,27%, while the rate of females was determined as 74,73%. In addition, the ♂:♀ ratio was 23,70% : 76,30% on the IPM plot. In 2016, the total number of females on the FMT plot was 5.039, and number of males was 1.607. The rate of females was determined as 75,82%, while the rate of males was 24,18%. A total of 6.857 adults were collected from the traps on the IPM plot in the second year of the study, and the ♂:♀ ratio was determined as 22,83% : 77,17%. It has been observed that the number of females captured in traps is three times higher than males.

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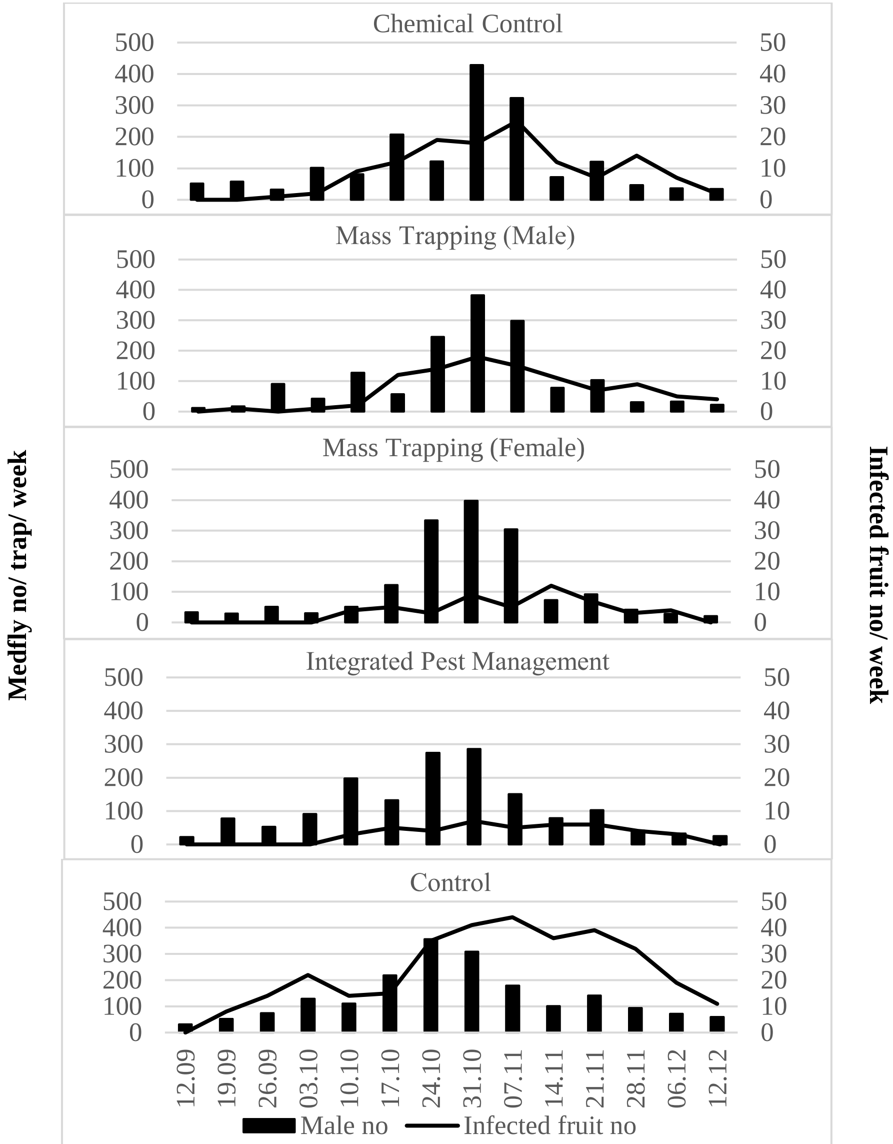

Figure 3. *The number of males captured in the Jackson traps and the infected fruits in the plots comparing different methods against Ceratitis capitata in Tarsus (Mersin) in 2016*

Fruit damage assessment

The average number of punctured fruits due to *C. capitata* infection in different applications is given in *Table 2*. In 2015, the first infected fruits were observed in the CC, MMT and Control plots on 24 September 2015, in the IPM plot on 01 October 2015 and on 08 October 2015 on the FMT plots (*Fig. 2*). Throughout the season, the highest number of infected fruits was observed in the Control plot (an average of 26.21 fruits). The maximum number of infected fruits (an average 43 fruits) on this plot was observed on 05 November 2015. This date corresponds to the week after the date when the highest number of adults were captured in the traps. The lowest number of infected fruits was observed on the IPM plot (an average of 3.29 fruits). Among the infected fruits throughout the season, it was observed that the difference between applications was statistically significant. CC, MMT, FMT and IPM plots were in the same group while the Control plot

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was in different group (F=16,919; df=4, 65; P<0.001). Similar results were also obtained in 2016 (*Fig. 3*). The number of infected fruits observed in the CC, MMT, FMT, IPM and Control plots throughout the season were 9.14, 7.07, 3.71, 3.07 and 23.57, respectively. Following the *C. capitata* infection, the difference between the weekly number of the dropped fruits was determined as statistically significant among the applications. CC, MMT, FMT and IPM plots were in the same group, while Control was in another group (F=15.388; df=4, 65; P<0.001).

Since all the applications were performed on the same orchard, impacts of the climatic factors affected all plots. No rainfall that required the applications to be repeated was experienced throughout the study. Therefore, it was considered that there were no conditions among applications that were caused by climatic factors (*Fig. 4*). The average temperature in august was 27.1 and 29.9°C in 2015 and 2016, respectively. The temperature followed a decreasing trend until harvest, but until November it was over 21°C both years. The relative humidity was over 50% and no heavy rainfall that limited the pest population occured during the study both years.

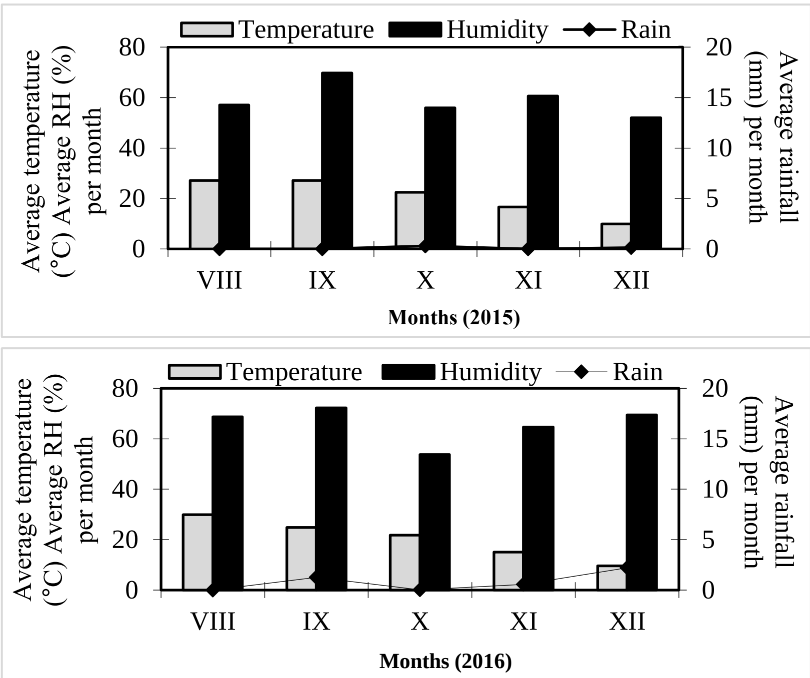

Figure 4. *Climatic datas in Tarsus (Mersin) in 2015 and 2016*

At the harvest, the efficiency of the CC, MMT, FMT and IPM applications against *C. capitata* in 2015 was 88.62%, 91.46%, 94.21% and 95.33%, respectively. The difference between the applications were statistically significant (F=10.892; df=3, 36; P<0.001). The CC, MMT, FMT and IPM applications showed average efficiency of 87.43%, 90.65%, 94.29% and 97.17%, respectively in 2016.

A statistical difference was determined between the applications (F=17.188; df=3, 6; P<0.001) and between the years (F=20.456; df=3, 6; P<0.001 in 2015, F=12.148; df=3, 6; P<0.001 in 2019). It was determined that the ratio of infected fruits in the IPM plot was lower than that of other plots (1.57% in 2015 and 0.89% in 2016) at harvest, followed by Biolure, Trimedlure and Spinosad, respectively (*Table 3*).

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Table 3. *Effect of the pest control techniques on the percentage of damaged fruits (mean±SE) at harvest in orange orchard in 2015 and 2016*

	% of infected fruits±SE	
Trials	**2015**	**2016**
Chemical Control	3.75±1.12 a* A**	3.94±1.33 a A
Mass Trapping (Male)	2.81±1.05 ab A	2.90±1.29 ab AB
Mass Trapping (Female)	1.96±0.77 bc B	1.78±0.71 bc BC
Integrated Pest Management	1.57±0.60 c B	0.89±0.53 c C
	F= 10,892	*F*= 17,188
	df= 3, 36	*df*= 3, 36
	P= 0,001	*P*= 0,000
Control	33.93	31.76

*Values followed by the same letter within a column, **Values followed by the same letter within a line are not significantly different at P<0.05

Discussion

Ceratitis capitata flight activity

Several mass trapping systems have been developed to control *C. capitata* worldwide. Depending on the strength of the attractant, this tactic targets females or males. In Turkey, there is very little mass trapping for the pest. Başpınar et al. (2011), Satar and Tireng (2016) and Demirel and Akyol (2017) reported that the mass trapping is being used successfully against *C. capitata*.

Results obtained from this study showed that considering all applications, pest population was determined to be high particularly from the second week of October until the mid of November in 2015 and 2016. The highest number of males was determined in the Control plot, however, no difference was determined among the applications both years. The fact that the number of males captured in the traps from different plots was not statistically different in both years has suggested that the pest showed homogeneous distribution among applications in the orchard. In 2015 and 2016, although the fruits had not reached infection maturity, the adults captured in the traps showed that the flies had flown to the study orchard from neighbouring orchards which had hosts of the pest. However, while pest population was low at the beginning of September, when the study started, the population increased when the fruits changed colour and the number of males captured in the traps was high in October and November. There are many studies in Turkey and in the world on the population dynamics of *C. capitata*. Katsoyannos et al. (1998) in their study performed in Chios (Greece) determined the highest number of adults captured in traps were in October and November. In addition, Martinez-Ferrer et al. (2010) determined similar results with mandarins in Spain and Boulahia-Kheder et al. (2012) with mandarins and oranges in Tunisia. Demirel and Akyol (2017) reported that pest population increased in October and November, in the mass trapping study performed with Eostrap invaginada traps in a satsuma mandarin orchard in Hatay (Turkey). Elekcioğlu (2013) stated that *C. capitata* population peaked in June, between 2008-2010 in a Washington navel orchard in Adana, which had similar climatic conditions to the orchard in the present study. The reason for this population increase during this period, when the fruits haven't yet reached infection maturity, is that there were other hosts for the pest around the study

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orchard and the fact that the pest reproduced. The pest population increased on these fruit trees and moved to citrus in the late summer or autumn. A high number of adults were captured from the mid of September until the mid of November in the study years and six to nine treatments were done per year on the citrus according to the weather conditions. The present study showed parallel results with the literature. It is considered that the high pest population and the fact that they reproduced in the citrus fruits during this period is due to the decrease in or non-existence of host plants, apart from the citrus species.

It has been observed that the number of females captured in traps is three times higher than males in the present study and in different studies from the literature that had different pest population, citrus type, traps, climatic conditions, etc. It is considered that capturing females is crucial for *C. capitata* control since the number of eggs laid decreases automatically. While males were captured primarily in the traps on MMT plot, females were also captured, even though the number of females was lower than males. Leza et al. (2008) determined that the rate of females varied between 70.10% : 78.70%, in which they used Biolure as a food lure and different insecticides. In their study performed on mandarins by using Tephri traps with attractants containing ammonium acetate, putrescine and trimethylamine as food, which is identical to the attractants used in the present study. Mediouni-Ben Jemâa et al. (2010) determined that the rate of females varied between 68.79% - 73.70% and 72.26% - 72.30% in a Washington navel orange orchard. Satar and Tireng (2016) determined the ♂:♀ rate as 27.00% : 73.00% and 31.00% : 69.00% in their mass trapping study, where they used ammonium acetate+chlorohydrate trimethylamine+diamineopentane as food for the pest control in an Okitsu wase mandarin orchard.

Fruit damage assessment

In all applications, the infected fruits were first observed at the end of September and the first half of October. After then, the number of infected fruits increased with the increasing pest population. The lowest number of infected fruits was observed in the IPM plot in both years. It is considered that the females were primarily attracted to the smell of the food and therefore directed to the traps with the yellow plates and did not infect the fruit in this plot. The bait application for suppressing the population in this plot during the high pest population contributed to reducing the population. The IPM plot was followed by FMT, MMT and CC plots, respectively.

The results show similarities with the study of Leza et al. (2008), who obtained the most successful result for *C. capitata* control when they used Biolure as attractant (50 Probodelt trap/ha) and one bait application of fenthion or Spinosad or lambda-cyhalothrin if required. The pest damage rate varies in the mass trapping studies in the literature on different citrus species. Boulahia-Kheder et al. (2010) reported more than 30% damage with only mass trapping in a Navel orange orchard in Tunisia. However, they determined a 5% damage rate on Navel orange at harvest with 4 foliar Spinosad treatments, sanitation and female mass trapping with Moskisan + Biolure as attractant (Boulahia-Kheder et al., 2015). In Spain, Martinez-Ferrer et al. (2012) detected <2% infected fruit rate with early maturing mandarin varieties (Loretina and Marisol) by using 50 Maxitrap (Probodelt®) traps/ha baited with Ferag CC D TM (SEDQ) + chemical treatments with Malathion or Spinosad. Nevertheless, it was determined that population decreased in midseason for Clemenules, and even in the case that the number of traps was reduced by half, the population still decreased, and less than 0.5% of infected fruit rate was detected. Demirel and Akyol (2017) determined 10.91% and 8.56% rate of infected fruits in 2011-2012, respectively, in a Satsuma mandarin orchard

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in Hatay (Turkey) by using Eostrap traps (48 traps/0.7 ha and 23 traps/0.7 ha) baited with 95% Trimedlure. In their study, they also used Eostrap traps, as this study, and obtained similar results despite having a higher number of traps per hectare. Yayla and Satar (2017) determined this rate as 8.57% in 2015 and 15.03% in 2016, in which they used Lastfly Ceratitis (4 traps/ha) traps for an Okitsu wase mandarin variety in Adana (Turkey). Various mass trapping systems have been developed worldwide for the control of fruit flies. These systems target capturing males or females according to the effect of the attractant. Better results have been reported from many mass trapping studies that used female-targeted attractants (Leza et al., 2008; Navarro-Llopis et al., 2008; Médiouni-Ben Jemaa et al., 2010; Trabelsi and Boulahia-Kheder, 2011; Boulahia-Kheder et al., 2015; Vargas et al., 2018). Biolure, which contains 3 synthetic components and targets mostly females, has been determined as one of the most suitable attractant for *C. capitata* (Epsky et al., 1999). In various Mediterranean countries, significant decreases have been reported in damage for citrus fruits or different hosts in IPM programs using this attractant (Navarro-Llopis et al., 2008; Martinez-Ferrer et al., 2012). The type of attractant is highly important for capturing a high number of females. The use of trimethylamine, the most efficient attractant, with ammonium acetate and with or without putrescine gives outstanding results against the pest (Heath et al., 2004). Food attractants containing more ammonium acetate and trimethylamine are most successful for capturing insects (Navarro-Llopis et al., 2008; Başpınar et al., 2011). Katsoyannos et al. (1999 a,b) determined that traps using 3-component synthetic lures are more specific for *C. capitata* than other female-targeted traps, and attract less non-target insects than 2-component lures and hydrolysed proteins. Broughton and De Lima (2002) reported a significant decrease in pest population and the number of infected fruits in their study in Western Australia using Biolure as an attractant compared to bait application using Spinosad. Furthermore, a higher number of females was captured by using Biolure, independent of trap type, climate, host plant or pest population. Miranda et al. (2001) stated that synthetic food lures (putrescine, ammonium acetate, and trimethylamine) were highly efficient on both high and low populations in their mass trapping study that targeted capturing *C. capitata* females in Spain. Mass trapping has been reported as an increasing controlling method in Turkey and worldwide against *C. capitata* in larger sized orchards (Broumas et al., 2002; McQuate et al., 2005; Demirel and Akyol, 2017; Yayla and Satar, 2017). Cohen and Yuval (2000) expressed that more successful results were obtained with increasing orchard size, and that this was due to the fact that trap systems and attractants are improved over time. In this study, as stated by researcher, regular implementation of control methods (chemical or biotechnological) in neighboring orchards, and regular collection and destruction of fallen fruits throughout the orchard contribute in reducing the pest population in the application orchard beyond any doubt. Organic farming orchards achieved the most success in *C. capitata* control due to the consumption of the fallen fruits by chickens and ducks, resulting in the destruction of pest larvae and pupae, in addition to mass trapping (80 traps/ha) (Leza et al., 2008). A more holistic and successful pest control is achieved in cases where several or all control methods consisting of biological, biotechnological, chemical and cultural practices are applied (Rachid and Ahmed, 2018). It can be suggested that the reason for the decreased pest population in some plots, as observed in this study, may be due to the decrease in the pest population posed with two years of trap application. However, it is thought that this should not be considered as a result that is always valid. Despite the regular pest control in an orchard, if there is no efficient control in neighbouring orchards, adults from these orchards will always pose a threat for the application orchard. The fact that the neighbouring

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orchards belong to the same producer, and that the producer applied control methods in these orchards contributed to the decrease in the population. The efficiency of pest control with mass trapping in wide areas has been observed better in this study.

Climate characteristics, besides food source, could influence the diversification of *C. capitata* activity, development and distribution (Cohen et al., 2008). *C. capitata* prefers hot and dry areas over wet and cold areas (Israely et al., 2005). Mersin Province which is in the Mediterranean region of Turkey has a Mediterranean climate: hot dry summer, wet mild winter. The optimum temperature for the development of this pest is between 21-26.7°C. The effect of rainfall on the medfly population has been related to a decrease in adult captures on rainy days and an increase a few days later, because flies are generally inactive during periods of moderate to heavy rainfall (Papadopoulos et al., 1996; Cohen et al., 2008). In the present study no heavy rainfall that limited the pest population occured during the study both years. Moustafa et al. (2014) mentioned that *C. capitata* population is significantly affected by some weather factors especially temperature degrees. Relative humidity plays a minor role in the build-up of the pest population (Ghanim and Moustafa, 2009; Ghanim, 2017). The average temperature in august was 27.1 and 29.9°C in 2015 and 2016, respectively. The temperature followed a decreasing trend until harvest, but until November it was over 21°C both years. The relative humidity was between 52% and 72%. Kasap and Aslan (2016) specify that the pest is active at daily average humidity of 40-80%. No heavy rainfall that limited the pest population occured during the study both years. According to Ghanim and Moustafa (2009) and Ghanim (2012, 2017), the activity of *C. capitata* is mainly correlated with the presence of fruit ripening of its host plants. It is unavoidable that global warming also will affect *C. capitata* population as other insects. *C. capitata* is likely to spread to other regions in Turkey in the near future (Kaya et al., 2017).

Conclusion

According to the results, the highest number of flies was detected in the Control plot (404 flies/trap/week) in 2015 and in Chemical Control plot (429 flies/trap/week) in 2016. Between the trials no statistical difference was found regarding the number of male flies weekly captured and number of infected fruits. The ratio of infected fruits in the IPM plot was lower than other plots (1.57% in 2015 and 0.89% in 2016) at harvest, followed by Biolure, Trimedlure and Spinosad, respectively. It was concluded that, the use of food lures to attract females, which are mainly responsible for the population growth of, was more ideal for mass trapping in the control of *C. capitata*, instead of traps using sex pheromones to attract males. IPM was the most effective control method for *C. capitata*. It is evident that the sanitation by eliminating the punctured fruits together with the bait application decreased the infected fruit number moreover the tolerance of the pest is ‘zero’ during export. Since citrus is an important export product for Turkey, a combination of several techniques as part of an integrated pest management approach can provide an inclusive, permanent and effective strategy, with a limited negative effect on the environment. It is unavoidable that global warming will affect *C. capitata* population. Therefore, the pest control may be necessary in winter months in the near future. Integrated control of *C. capitata*, if properly carried out, thought to be successful in minimizing the pest population. In order for the IPM programme for the pest to be successful, an organization must be established, cooperation between growers, extension agents and researchers encouraged and a national policy drawn up that supports the IPM programme for citrus.

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