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RESEARCH PAPER

HORTICULTURAL STUDIES

Field Study on Mass-Trapping for the Control of Mediterranean Fruit Fly, *Ceratitis capitata* (Wiedemann, 1824), in Orange Orchards in Türkiye

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Abstract

Ceratitis capitata (Wiedemann, 1824) (Diptera: Tephritidae), is a destructive quarantine pest that causes significant economic damage to fruit crops. Chemical control is a common method used against this pest, but it has harmful effects on the environment and human health. Biotechnical control is one of the most eco-friendly control methods and has been used successfully against *C. capitata*. The main objective of this study was to determine the efficacy of mass trapping as a biotechnical control method in orange orchards located in three different regions of Türkiye: Mersin, Aydın, and Adana. The study found that the average number of *C. capitata* in decis traps was 94.5, 30.9, and 114.4 in Mersin, Aydın, and Adana, respectively. The corresponding numbers in pheromone traps (control parcels) were 193.3, 70.4, and 221.1. The efficacy of traps was determined with four traps per decare for each location and efficacy was 90.05%, 93.43%, and 94.01% in Mersin, Aydın, and Adana, respectively. Mass trapping can be an effective strategy to control *C. capitata* populations as part of Integrated Pest Management programs. By adopting sustainable and effective methods like mass trapping, the negative effects of chemical control can be reduced. Farmers should be informed about the effectiveness and importance of biotechnical control methods and consider adopting them as part of their pest control practices to protect their fruit crops and preserve the environment and the community's health.

1. Introduction

Mediterranean fruit fly (*Ceratitis capitata*, Wiedemann, 1824) (Diptera: Tephritidae) has been causing damage and economic losses in fruit orchards in tropical and subtropical regions since 1829 (Bodenheimer, 1951; Demirdere, 1961; Headrick and Goeden, 1996). *C. capitata* is polyphagous species that cause damage to many fruits and vegetables (Bircan et al., 2020; Elekçioğlu, 2009; Elekçioğlu, 2013; Orono et al., 2006; Papadopoulos, 2008; Satar et al., 2016; Satar and Tireng, 2016). *C. capitata* was reported as a pest in 21 different plant species from 7 families, and 17 of them are important host plants for this pest in Türkiye (Zümreoğlu, 1986), and the Citrus genus is one of them. In addition, peach, apple, quince, apricot, persimmon, plum, pomegranate, and avocado are also host plants for *C. capitata*, and this pest causes critical damage to these species (Demirdere, 1961; Demirel, 2016; İleri, 1961; Karsavuran et al., 1988; Kaya and İpekdal, 2018; Tiring and Satar, 2017; Tunçyürek, 1972; Zümreoğlu, 1986; Zümreoğlu,1990).

Ceratitis capitata, which causes economic loss on products, cannot be suppressed without

applying control method. Tolerance of *C. capitata* is zero in terms of quarantine. The entire product is rejected if even a single fruit is contaminated with this pest in export. The products were returned to Türkiye due to the suspicion of *C. capitata* in the mandarin fruits exported to the Russian Federation in 2009 (Özbay, 2011). Currently there are four approaches to control *C. capitata*; Sterile Insect Technique (SIT), mass trapping, pesticide bait spray mixture and cover spraying (Yayla and Satar, 2017). Pesticide bait spray mixture and cover spraying with unlicensed pesticides and biotechnical control are the most common methods against this pest in Türkiye. Chemical control is primarily used in these methods in Türkiye, but if farmers do not apply appropriate doses and registered pesticides, it will cause in residue problems fruits. Insecticides used against *C. capitata* for Satsuma Mandarin and pomegranate, were analyzed for residue, and maximum residue limit (MRL) values of malathion were higher than the European Union MRL values (Dinçay et al., 2017). Higher MRL values are a critical risk for human health and exportation.

Biotechnical control methods in Integrated Pest Management (IPM) have been studied and used instead of traditional chemical control. The most common and successful methods for *C. capitata* are mass trapping and lure-kill (LK). The main objectives of the above alternative methods are to decrease spraying applications or combine them with other control methods within IPM (Layık and Kısmalı, 1994).

There are many studies about the control of *C. capitata* with trapping (Akman & Zümreoğlu, 1973; Akyol, 2014; Başpınar et al., 2009; Delrio and Zümreoğlu, 1983; Elekçioğlu et al., 2011; Satar and Tireng, 2016; Sierras et al., 2012; Yayla and Satar, 2017). However, these studies were conducted at different times and in regions separately, and there are no data about working and sharing simultaneously in two regions in the same year. This study aimed to determine the possible use of the same number of traps against *C. capitata* in two locations in the Mediterranean and one location in the Aeagen Regions of Türkiye. In addition, in this study, biological efficacy experiments in field conditions against *C. capitata* were conducted to contribute to the increase in the use of traps and to decrease the cost of chemical pesticides.

2. Material and Methods

Field experiments were conducted in 1.2 ha orange orchards (Washington navel) at Alata Horticultural Research Institute in Erdemli-Mersin, 1.4 ha orange orchards in Kozan districts of Adana and in 1.5 ha orange (Fukumoto) orchards in Kuşadası (Davutlar)-Aydın in 2017. Experiments consisted of trap plots and control plots (without any insecticides). Decis traps (0.015 g deltamethrin + 7.8 g ammonium acetate + 0.5 g chlorohydrate trimethylamine + 0.03 g 1.5 diamineopentane/trap) were used for mass trapping, and delta traps (Trimedlure) were used for monitoring.

2.1. Field experiments

A total of twelve hectares orange orchards (Washington navel) were chosen for the field experiment in Erdemli-Mersin. The size of control parcels was about 0.1 ha and the distance was 100 m from trap parcels. The east side of the trap parcel was an olive orchard, the west side was lemon and mandarin, the south was grapefruit, and the north was olive orchards. The soil structure of the experiment area was sandy-loamy and had good water permeability. The age of oranges in the experiment was 12-14 years, and the distribution of trees was homogeneous. A drip system was established for the trees' water needs, and irrigation was done according to the needs of the plants.

One point four hectares orange orchards (Washington navel) were chosen for the field experiment in Kozan-Adana. The size of control parcels is about 0.1 ha and the distance was 125 m from trap parcels. The east side of the trap parcel was an olive orchard, the west side was mandarin, the south was orange, and the north was maize. The age of oranges in the experiment was 16-18 years, and the distribution of trees was homogeneous. The soil structure of the experiment area was sandy-loamy and had good water permeability. A drip system was established for the trees' water needs, and irrigation was done according to the needs of the plants.

One and a half hectares orange orchards (Fukumoto) were chosen for the field experiment in Kuşadası/Davutlar-Aydın. The size of control parcels was about 0.1 ha and the distance was 100 m from trap parcels. The soil structure of the experiment area was sandy-loamy, and a drip system was used for irrigation. The experiment area's north, east, and west sides were peach and mandarin, and the south was mandarin. Insecticide applications were not applied to the two orchards during the experiments. Fields were chosen to represent the region where citrus cultivation is dominant in both regions. The effectiveness experiment was carried out according to a pairing design, and the control parcel size was arranged as 0.1 ha. For monitoring, delta traps with pheromone were hung one trap/100 trees (three traps in total), and one trap for the control parcel. Capsules in Pheromones traps were changed every 4-5 weeks, and the sticky platform was changed when it was dirty. Experiments were done 1.4 ha orchard in Kozan-Adana, 1.1 ha in Erdemli-Mersin, and 1.5 ha in Davutlar-Aydın. Fourty traps per ha for mass trapping were hung when the first adult was seen in monitoring traps on 08.09.2017 in Erdemli-Mersin, fourty traps per ha for mass trapping were hung on

01.09.2017 in Davutlar-Aydın, and fifty traps per ha for mass trapping were hung on 22.09.2017 in Kozan-Adana. All traps were hung at the south of the trees and at 1.5-1.8 m in height. Although traps were hung frequently along the edge of the orchard to create a buffer zone and prevent contamination from outside, the number of traps used within the orchard was controlled.

2.2. The determination effectiveness of mass-trapping

Fourteen trees in Kozan, 15 in Davutlar, and 11 in Erdemli were marked for analysis. Infected and non-infected fruits were counted and recorded weekly in the control plots and removed from under the trees. The number of total fruits, infected fruit, infestation rate and % relative effect on the marked trees in treatment (40 mass trapping traps per ha) and control parcel in Kozan-Adana, Erdemli-Mersin, and Davutlar-Aydın. The results were presented with accompanying figures. The percentage differences between infected fruits were calculated using the Abbott formula (Abbott, 1925) and statistical differences were analysed using the Chi-square method. Statistical analysis was conducted using SPSS 23 software.

3. Results and Discussion

3.1. Population fluctuations of Mediterranean fruit fly (MEDfly)

Figure 1 shows the population changes observed in decis traps in the treatment parcels and

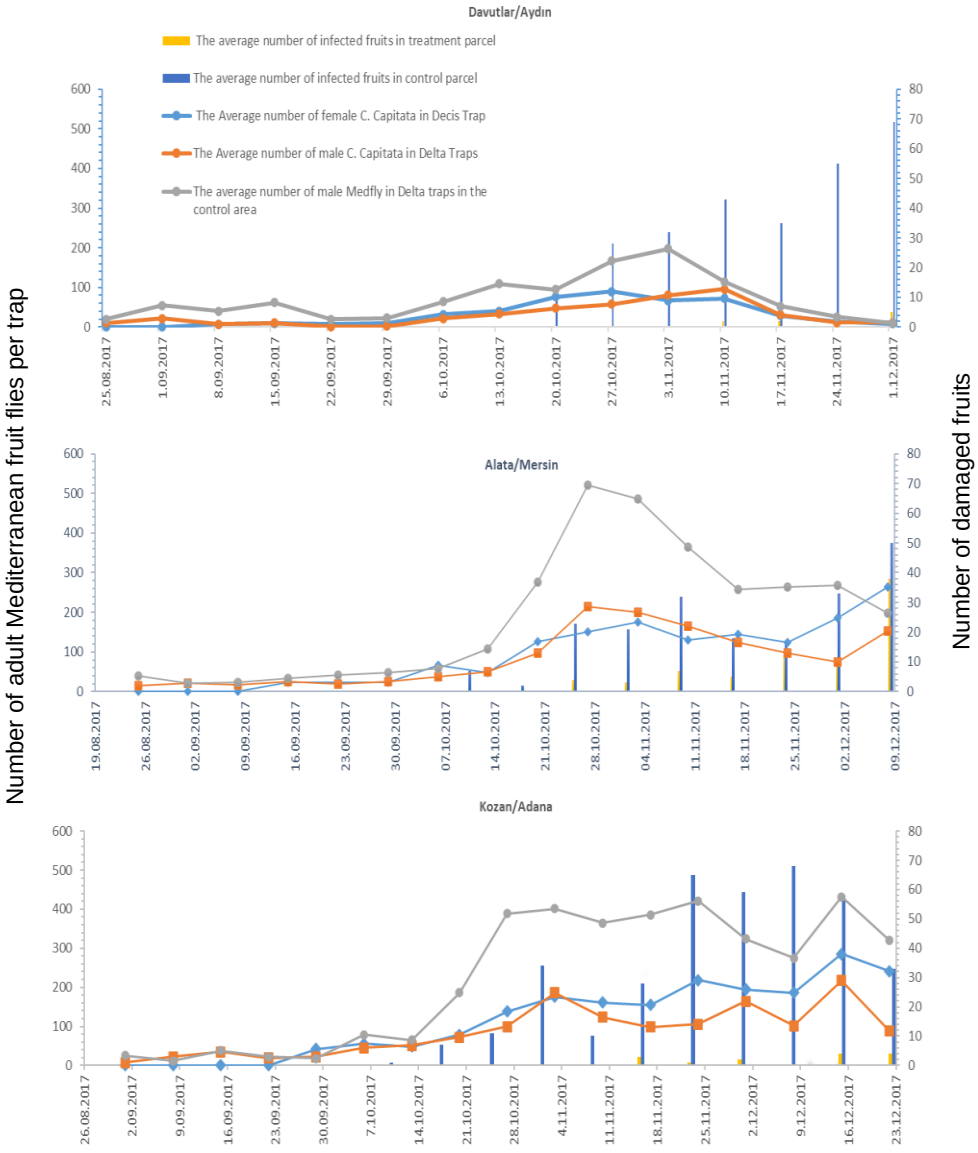

Figure 1. The population dynamics of adult *Ceratitis capitata* in the mass trapping decis trap and delta trap (control parcel) in orange orchards in Aydın-Davutlar, Adana-Kozan and Mersin-Erdemli (Alata) provinces.

delta traps with pheromones in the control parcels. These changes were determined by calculating the average number of *C. capitata* adults captured in decis traps and delta traps in the Erdemli, Davutlar, and Kozan study sites.

On August 18, 2017, a delta trap with pheromone was hung in Aydın-Davutlar. Subsequently, 112 and 40 *C. capitata* adults were captured on August 25 and September 1, 2017, respectively. On September 1, 2017, a decis trap was also hung for mass trapping in the experimental area, and the average number of adult MEDfly recorded in these traps on September 8, 2017, was 7.35. The maximum number of adult MEDfly captured in the decis trap was 89.8 on October 27, 2017, while the delta trap with pheromone in the control parcel captured 217 adults on November 3, 2017 (Figure 1). In addition to trap data, changes in fruit color were monitored and recorded in the orchards. It was observed that fruit color began to change when the population increased in traps on October 13, 2017. The percentage of orange color rate increased from 25% on October 20, 2017, to 85% on November 10, 2017. The population increase observed during the color change period may be associated with the oviposition preference of *C. capitata*

The delta traps, used to determine the MEDfly population, were hung in Kozan-Adana on 01.09.2017. The average number of MEDfly adults was 35 and 38 on 08.09.2017 and 15.09.2017, respectively. A decis trap for mass trapping was hung in the orchard on 22.09.2017. On 29.09.2017, the average number of MEDfly adults was 42.1 in the decis trap and 79 in the delta trap (control parcel) in the experimental area. The maximum population level was 256 in the decis trap on 24.11.2017 and 438 in the delta trap on 03.11.2017, as shown in Figure 1. Changes in fruit color were monitored and recorded in the orchards. As the population increased in the traps on 10.11.2017, the color of the fruit changed. The orange color rate was recorded as 45% on 01.11.2017, and during our observation, it increased to 95% on 10.11.2017.

In Erdemli-Mersin, the MEDfly population was monitored using delta traps hung on 25.08.2017. The traps captured an average of 24 and 26.5 MEDfly adults on 01.09.2017 and 08.09.2017, respectively. On 08.09.2017, a decis trap was hung in the orchard for mass trapping. On 15.09.2017, the average number of MEDfly adults was 22.9 in the decis trap and 33 in the delta trap (control parcel) in the experimental area. The maximum population level was 175.2 in the decis trap on 03.11.2017, while the delta trap (control parcel) reached a peak of 522 on 27.10.2017 (Figure 1). Fruit color change was monitored and recorded in the orchards. When the population in the traps increased on 06.10.2017, the color of the fruits started to change. The orange color rate was measured at %30 on 27.10.2017, and it increased to 90% on 10.12.2017 during our observation period.

The study claimed that the effects of climate on *C. capitata* population were similar in the experimental areas across three provinces, as shown in Table 1. Daily average temperature (°C), daily average relative humidity (%), and daily Soil temperature at 10 cm depth (°C) were hypothesised to influence the MEDfly population. The results may be associated with climate parameters that variations in the number of adult *C. capitata* in the different regions were due to differences in the host plant range.

3.2. The determination of the biological efficacy of mass-trapping

The countings on infected and non-infected fruits were done randomly on the treee and on the ground in experimental areas in Mersin-Erdemli, Aydın-Davutlar, and Adana-Kozan. The number of infected and non-infected fruits and % relative effect were determined and given with figures.

On 27.10.2017 in Mersin-Erdemli, no infected fruits were found on the ground, while infected fruits were observed in the control parcel. The rate of fruit damage by MEDfly was 13.79% and 17.74% on 27.10.2017 and 03.11.2017, respectively. Larvae of MEDfly were also detected in the infected fruits. The infestation rate increased as the pest population grew, and the efficacy of the traps decreased to 79.31% during the subsequent counting sessions (Table 2). On 08.12.2017, which marked the beginning of the harvest and the end of the experiment, the efficacy of the traps was 90.5%, whereas the infestation rate in the control parcel was 23.92% (Table 2). According to the Chi-square test results, the percentage of total infected fruits was 71.7% in the control parcel and 28.3% in the treatment parcel. In contrast, 50.3% of total non-infected fruits were in the treatment parcel and 76.9% in the control parcel. Moreover, 82.7% of the total number of fruits was non-infected in the treatment plot, and 17.3% was non-infected in the control plots. The difference between mass-trapping and control was statistically significant based on the Chi-square test (x^2: 45.509; $P<0.05$; df:1).

In Aydın-Davutlar, 18.86% of fruits in the control parcels were found to be infected from 20.10.2017. The average damage rate by weekly countings after this date was 48.33% in the control parcel. The damage rates in the control parcel by MEDfly were 18.86% and 46.66% on 20.10.2017 and 27.10.2017, respectively, and larvae of MEDfly were observed in infected fruits. The infected fruits were still found, and the efficacy decreased to %87.87 as the pest population increased in the control parcel during the continuation of the experiment. The effectiveness of the traps was 93.43% on 08.12.2017, which was the beginning of

Table 1. The average climate parameters of Davutlar-Aydın, Erdemli-Mersin, and Kozan-Adana provinces.

Locations	Months						
Davutlar–Aydın	June	July	August	September	October	November	December
Daily maximum temperature (°C)	33.87	39.93	36.77	34.76	28.31	20.46	17.94
Daily minimum temperature (°C)	19.35	22.40	22.23	18.00	12.88	7.99	7.86
Daily average temperature (°C)	26.10	29.85	28.78	24.75	18.76	12.47	11.26
Daily soil temperature 10 cm depth (°C)	26.53	36.00	33.82	30.24	21.59	12.90	10.94
Daily average relative humidity (%)	52.12	43.28	52.00	50.47	56.71	70.34	74.03
Daily total precipitation (mm)	2.19	0.00	2.94	0.00	4.45	13.41	6.13
Daily average wind speed (m sn^{-1})	1.30	1.35	1.27	1.09	1.17	1.18	1.50
Erdemli–Mersin	June	July	August	September	October	November	December
Daily maximum temperature (°C)	28.73	33.39	34.15	32.80	28.19	23.81	18.56
Daily minimum temperature (°C)	22.86	27.01	27.06	24.67	18.44	13.22	11.16
Daily average temperature (°C)	25.85	30.04	30.01	28.11	22.91	17.12	14.63
Daily soil temperature 10 cm depth (°C)	31.73	36.76	36.37	33.28	25.11	16.43	12.91
Daily average relative humidity (%)	66.84	63.85	62.30	59.39	44.00	52.94	55.00
Daily total precipitation (mm)	0.28	0.00	0.25	0.43	0.33	4.38	1.05
Daily average wind speed (m sn^{-1})	1.52	1.53	1.20	1.38	1.10	1.02	0.94
Kozan- Adana	June	July	August	September	October	November	December
Daily maximum temperature (°C)	30.67	38.73	35.23	35.73	30.73	22.48	19.97
Daily minimum temperature (°C)	21.15	25.39	25.98	23.14	16.47	11.95	9.06
Daily average temperature (°C)	26.16	30.39	29.89	27.88	22.27	15.94	12.67
Daily soil temperature 10 cm depth (°C)	36.38	36.11	32.55	24.70	16.02	12.17	12.02
Daily average relative humidity (%)	69.38	64.26	67.51	68.28	52.45	66.20	74.25
Daily total precipitation (mm)	0.57	0.00	0.00	0.36	1.24	4.09	1.03
Daily average wind speed (m sn^{-1})	1.58	1.71	1.66	1.43	1.21	1.36	1.22

Table 2. The number of total fruit, infected fruit, infestation rate and % relative effect on the marked trees on treatment (40 mass trapping traps per ha) and control parcel in the Mersin-Erdemli district.

Date	Treatment parcel			Control parcel			Relative effect (%) (Abbott formula)
	Number of fruits falling to the ground			Number of fruits falling to the ground			
	Non-infected fruit	Infected fruit	Infection rate (%)	Non-infected fruit	Infected fruit	Infection rate (%)	
25.08.2017	0	0	0	0	0	0	-
01.09.2017	0	0	0	0	0	0	-
08.09.2017	0	0	0	0	0	0	-
15.09.2017	0	0	0	0	0	0	-
22.09.2017	0	0	0	0	0	0	-
29.09.2017	0	0	0	0	0	0	-
06.10.2017	0	0	0	0	0	0	0
13.10.2017	0	0	0	0	0	0	0
20.10.2017	10	0	0	28	0	0	0
27.10.2017	30	0	0	58	8	13.79	86.67
03.11.2017	25	0	0	62	11	17.74	88.00
10.11.2017	38	7	18.42	97	25	25.77	81.58
17.11.2017	30	5	16.66	62	18	29,03	83.33
24.11.2017	58	12	20.68	52	17	32.69	79.31
01.12.2017	100	11	11.00	144	33	22.91	89.00
08.12.2017	400	38	9.50	209	50	23.92	90.50

the harvest and the end of the experiment, according to the total fruit counts (Table 3).

The Chi-square test results revealed that 97.1% of total infected fruits were in the control parcel, while only 2.9% were in the treatment parcel. 96.6% of total non-infected fruits were from the treatment parcel, and 70.6% were from the control parcel. 73.1% of the total number of fruits was non-infected and obtained from the treatment parcel, while only 26.9% was non-infected and obtained from the control parcel. The difference between the mass-trapping and control was statistically significant with the Chi-square test (x^2: 229.07; $P < 0.05$; df:1).

In Adana-Kozan, 4.54% of fruits in control parcels were found to be infected on 13.10.2017. Subsequently, weekly counts showed an average damage rate of 39.84% in the control parcel, with 8.13% and 19.64% damage rates by MEDfly on 20.10.2017 and 27.10.2017, respectively, with the observation of MEDfly larvae on infected fruits. The efficacy of mass-trapping traps was 85.98% as the pest population increased during subsequent counts. At the beginning of the harvest and the end of the experiment on 22.12.2017, the decis trap efficacy was 94.10% according to total fruit counts in Table 4.

Table 3. The number of total fruit, infected fruit, infestation rate and % relative effect on the marked trees on treatment (40 mass trapping traps per ha) and control parcel in Aydın-Davutlar district.

Date	Treatment parcel			Control parcel			Relative effect (%) (Abbott formula)
	Number of fruits falling to the ground			Number of fruits falling to the ground			
	Non-infected fruit	Infected fruit	Infection rate (%)	Non-infected fruit	Infected fruit	Infection rate (%)	
25.08.2017	0	0	0	0	0	0	-
01.09.2017	0	0	0	0	0	0	-
08.09.2017	0	0	0	0	0	0	-
15.09.2017	0	0	0	0	0	0	-
22.09.2017	0	0	0	0	0	0	-
29.09.2017	0	0	0	0	0	0	-
06.10.2017	0	0	0	0	0	0	0
13.10.2017	0	0	0	20	0	0	0
20.10.2017	0	0	0	53	10	18.86	0
27.10.2017	0	0	0	60	28	46.66	0
03.11.2017	19	0	0	82	32	39.02	0
10.11.2017	28	2	7.14	73	43	58.90	87.87
17.11.2017	52	2	3.84	153	88	57.51	90.85
24.11.2017	136	4	2.95	183	95	51.91	92.14
01.12.2017	129	5	3.87	325	163	50.15	92.28
08.12.2017	252	9	3.57	531	289	54.42	93.43

Table 4. The number of total fruit, infected fruit, infestation rate and % relative effect on the marked trees on treatment (40 mass trapping traps per ha) and control parcel in Adana-Kozan district.

Date	Treatment parcel			Control parcel			Relative effect (%) (Abbott formula)
	Number of fruits falling to the ground			Number of fruits falling to the ground			
	Non-infected fruit	Infected fruit	Infection rate (%)	Non-infected fruit	Infected fruit	Infection rate (%)	
01.09.2017	0	0	0	0	0	0	-
08.09.2017	0	0	0	0	0	0	-
15.09.2017	0	0	0	0	0	0	-
22.09.2017	0	0	0	0	0	0	-
29.09.2017	0	0	0	0	0	0	-
06.10.2017	0	0	0	0	0	0	-
13.10.2017	0	0	0	22	1	4.54	0
20.10.2017	0	0	0	86	7	8.13	0
27.10.2017	32	0	0	56	11	19.64	0
03.11.2017	25	0	0	162	34	20.98	0
10.11.2017	19	0	0	48	10	20.83	0
17.11.2017	58	3	5.26	75	28	37.33	85.98
24.11.2017	26	1	3.84	95	65	68.42	96.19
01.12.2017	32	2	6.25	86	59	68.60	92.94
08.12.2017	15	0	0.00	198	68	34.35	100.00
15.12.2017	97	4	4.12	102	58	56.86	92.74
22.12.2017	106	4	3.77	52	33	63.46	94.10

According to the Chi-square test's cross-comparison (Fruit*application) results, 96.4% of the total infected fruits were in the control parcel, while 3.6% were in the treatment parcel. For non-infected fruits, 96.7% were in the treatment parcel, while 72.0% were in the control parcel. Among the total number of fruits, 78.0% were non-infected and obtained from the treatment parcel, while 22.0% were non-infected and obtained from the control parcel. The Chi-square test revealed that the difference between the mass-trapping and control was statistically significant (x^2: 114,085; $P < 0.05$; df:1).

The study showed that the average MEDfly population in decis trap between September-December was 94.5 and 193.3 in the pheromone trap in Mersin-Erdemli. Similarly, the average MEDfly population in decis trap between September-December was 30.9 and 70.4 in the pheromone trap in Aydın-Davutlar. In Adana-Kozan, the average MEDfly population in decis trap was 114.4, and 221.1 in the pheromone trap. The study concluded that the MEDfly population was higher in Mersin-Erdemli compared to Aydın-Davutlar and the highest values were obtained from Adana-Kozan. The efficacy of traps was found to be 90.05% in Erdemli, 93.43% in Davutlar, and 94.01% in Kozan.

Recent studies have demonstrated that mass trapping has emerged as a highly effective strategy for managing *C. capitata* populations within Mediterranean agroecosystems. This success can be largely attributed to the innovation of advanced female attractant dispensers, which utilize a

combination of ammonium acetate, trimethylamine, and putrescine (Heath et al., 1997). Alemany et al. (2004) demonstrated the effectiveness of mass trapping in Spanish citrus orchards, achieving satisfactory control levels using a three-component female-targeted lure. The trials were conducted in orchards with highly susceptible citrus varieties, specifically late-ripening varieties maturing in summer, characterized by elevated populations of *C. capitata*. A density of 165 Tephri-Traps per ha was deployed. However, the study did not include a direct assessment of fruit damage in the control plots; thus, the efficacy of mass trapping was inferred from historical data on fruit infestation. Despite this limitation, the study indicated a significant reduction in *C. capitata* populations, as indicated by monitoring trap data throughout the trial period, with female captures declining from 205 females per trap per day in the control plot to 2.82 females per trap per day in the mass trapping plot.

Previous research indicates that the population of MEDfly is higher between August-September in Adana, and mass trapping using 1180 traps/225 ha, including Trimedure and DDVP reduced the spraying from 9 to 5, resulting in successful control (Elekçıoğlu et al., 2011). The population of *C. capitata* was higher in peach between May-July, in grapefruit between May-September, in persimmon in July, September, and October, and in pomegranate in September, October, and November (Kasap and Aslan, 2016; Satar et al., 2016; Tiring and Satar, 2017). Mediterranean fruit fly populations were observed between April and November, with an increase between August and September in Karaburun and Menderes (Tolga et al., 2019). The study also showed that McPhail traps, including borax, trimedlure, and Nu-Lure combinations, were the most effective traps against *C. Capitata* in citrus, apricot, and peach orchards (Zümreoğlu, 1990). In greenhouse conditions, McPhail traps were the most effective among delta, pet, circular and McPhail traps that included liquid hydrolyzed protein attractants (Souza et al., 2016). In Spain, 25 and 50 traps per ha were effective against *C. capitata* in citrus orchards (Martinez-Ferrer et al., 2012). In Hawaii, three-component dry traps were effective against MEDfly between 6-10 weeks (Jang et al., 2007). Mediouni et al. (2010) found that deploying 20 traps per ha was effective in significantly reducing *C. capitata* fruit damage in mandarin orchards compared to malathion bait sprays. Martínez-Ferrer et al. (2012) evaluated a novel dispenser containing a blend of ammonium acetate, trimethylamine, and cadaverine, used in the probodelt trap. This research demonstrated that a lower density of 25 traps per ha was adequate to control damage in mid-season varieties, when pest pressure was low. However, for early-ripening varieties, which experience higher pest pressure, a greater trap density was necessary. Additionally, Navarro-Llopis et al. (2012) observed that deploying 50 traps per ha effectively reduced fruit infestation rates to below 0.5% in susceptible citrus varieties with high *C. capitata* populations. This reduction was highly significant when compared to control plots, which lacked efficient attractants and exhibited fruit damage levels 5 to 12 times greater than those in mass trapping plots or in plots treated with weekly spinosad + bait applications.

The intensity of pest pressure is a critical consideration, as the cost-effectiveness of mass trapping is constrained by economic limitations. In scenarios with high fruit fly populations, the density of traps required may affect this approach financially impractical. In such cases, insecticide treatments are recommended when infestation levels surpass established damage thresholds. However, the impact of mass trapping on these thresholds remains uncertain. For instance, in both Spain and the United States, control measures against *C. capitata* are advised in citrus orchards with >0.5 flies per trap per day (FTD), as determined using Nadel traps baited with trimedlure (USDA, 2002), to maintain fruit infestation rates below 1.5% (Navarro-Llopis et al., 2011). Navarro-Llopis et al. (2010) investigated the impact of various trap densities on *C. capitata* populations and fruit damage in Mediterranean citrus orchards. The study, conducted in Spain with highly susceptible early-ripening clementine varieties, demonstrated that deploying traps baited with a mixture of ammonium acetate, trimethylamine, and methylpyrrolidine at a density of 50 traps per ha significantly reduced fruit damage compared to orchards treated with two bait sprays of lambda-cyhalothrin. However, significant protection against fruit damage was achieved only at higher trap densities, specifically 75 or 100 traps per ha.

Another study found that traps remained effective for 12-13 weeks in the experimental areas capturing the adults of *C. capitata* in Kuşadası (Aydın), Selçuk (İzmir), and Erdemli (Mersin), fifty traps per ha were found effective, with 4.8, 149.1, and 166.9 adults captured, respectively. The effectiveness of traps was 94.19%, 95.6%, and 56.34%, respectively, in Kuşadası, Selçuk, and Erdemli. However, fifty traps per ha were unsuccessful in the Mediterranean Region, where the *C. capitata* remains longer due to the long duration of peach production season, compared to the Aegean region (Yayla et al., 2022).

4. Conclusion

This study highlights the importance of adjusting the number of traps per unit area according to pest population levels in fruit fly management. Higher pest populations, especially in *C. capitata*, required more traps per unit area for successful masstrapping. Insecticide application combined with traps has also been reported as a more practical approach for controlling Mediterranean fruit fly populations in areas with high pest densities.

Using varying traps per unit area based on pest populations can be more effective and efficient in suppressing pest populations. If increasing the number of traps is not possible, integrating biotechnical methods with cultural and chemical control, or early harvest can be recommended. It should be noted that delaying harvest due to economic concerns may result in increased damage caused by fruit flies. Therefore, timely harvest and implementation of integrated pest management strategies are crucial in reducing economic losses caused by fruit fly infestations.

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