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Evaluation of the efficiency of mass trapping of *Ceratitis capitata* in citrus orchards of Northern Iran

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Abstract

The Mediterranean fruit fly (Medfly), *Ceratitis capitata* (Wiedemann, 1824) is one of the most destructive pests of citrus fruits in Mazandaran province of Iran. The mass trapping approach based on using female and male-targeted attractants was carried out in a citrus grove, mainly early ripening clementine variety with a few number of fig, persimmon and pomegranate trees (1 ha) using Tephri-trap (with Cera-lure as a food attractant for females) and Jackson trap (with Trimedlure as a sexual attractant for males) and control plot (0.5 ha) in two successive years. In total 93 traps were installed and distributed on one-third of citrus trees in treated plots. All traps were placed 1.5-2 m above the ground, slightly inside of trees canopy. For each Jackson trap, three Tephri-traps were set. Monitoring of adult populations of Medfly in the treated and control plot was performed using two Delta traps per plot. Tephri-traps were serviced once every two weeks and Trimedlure dispensers of Jackson traps were replaced every two months. The achievement of mass trapping was on randomly examining of 100 fruits every week from September until harvesting time (i.e. November). At the end of experiment, approximately 35010 female and 4333 male flies were trapped in the treated orchard. Data analysis indicated significant differences (P<0.0001, df=11, t=32.22) between fruit infestation percentage to the Medfly in treated and control plots. The pest control was fully satisfactory and fruit damage by Medfly was less than 0.5%, compared to the control plot (40%).
Keyword: *Ceratitis capitata*, Jackson trap, mass trapping, Tephri trap, Mazandaran

ارزیابی شکار انبوه مگس میوه مدیترانه‌ای *Ceratitis capitata* Wiedemann در باغات مرکبات شمال ایران

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چکیده

مگس میوه مدیترانه‌ای یکی از مخرب‌ترین آفات میوه مرکبات در استان مازندران است. مطالعه ارزیابی شکار انبوه بر پایه جلب کننده‌های جنس نر و ماده مگس میوه، در باغات نارنگی انشو زودرس (۱ هکتار) با تعدادی از درختان انجیر، خرمالو و انار و باغ شاهد (۰/۵ هکتار)، با استفاده از تله تفری تراپ با ماده جلب کننده تغذیه‌ای سرالور (شکار حشره ماده) و تله جکسن با ماده جلب کننده جنسی تری‌مدلور (شکار حشره نر) در دو سال پیاپی انجام شد. در مجموع تعداد ۹۳ عدد تله روی یک سوم از درختان باغ نصب شد. تله‌ها در ارتفاع ۲-۱/۵ متر از سطح زمین، اندکی در سایه انداز درختان نصب شدند. به ازای هر تله جکسن، سه تله تفری تراپ در باغ نصب شد. پایش حشرات کامل مگس میوه در باغات تیمار شده و شاهد با استفاده از دو عدد تله دلتا انجام شد. مایع سرالور تله تفری تراپ و تری مدلور تله جکسن به‌ترتیب هر دو هفته و دو ماه تعویض شدند. ارزیابی شکار انبوه با بازرسی تصادفی هفتگی از تعداد ۱۰۰ عدد میوه از شهریور تا آبان انجام شد. در مدت مطالعه، تعداد ۳۵۰۱۰ و ۴۳۳۳ عدد حشره ماده و نر توسط تله‌ها شکار شدند. آنالیز داده‌ها نشان داد که اختلاف معنی‌داری بین درصد میوه‌های آلوده در باغ شاهد و تیمار شده وجود داشت. کنترل آفت در باغ تیمار شده با ترکیب جلب کننده‌ی نر و ماده بسیار رضایت‌بخش بود و خسارت میوه در باغ تیمار شده کمتر از ۰/۵ درصد در مقایسه با باغ شاهد (۴۰ درصد) بود.
واژه‌های کلیدی: تله تفری تراپ، تله جکسن، شکار انبوه، مازندران، مگس میوه

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Introduction

The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), is one of the most devastating pests of fruits and vegetables in worldwide (Liquido *et al*., 1997). It is a highly polyphagous insect which attacks more than 300 different species of horticultural products such as peach, nectarine, apple, pear, fig, persimmon, plum and citrus (Christenson & Foote 1960). In citrus orchards, the pest causes damage on early ripening varieties like Clementine (*Citrus reticulate* Blanco and *C. aurantium*) (Mafi, 2012).

Mass trapping has been known as an effective control method against different fruit fly species in low levels of population. It involves setting a network of specific traps with effective lure in fruit orchards to capture and knock out target pest. Highly effective attractant materials are available for the aimed species. Various field tests were conducted to evaluate the efficacy of mass trapping as a control method on different fruits such as citrus (Fabregues *et al*., 1998), peach (Sastre, 1999), persimmon and coffee (McQuate *et al*., 2005), fig (Llorens *et al*., 2004) and apple (Escudero *et al*., 2005) with promising results. Other investigations have also indicated that mass trapping with traps baited with synthetic food attractants successfully have controlled the Mediterranean fruit fly in Spain (Navarro-Llopis *et al*., 2008; Martinez-Ferrer *et al*., 2012).

In Iran, Mediterranean fruit fly *C. capitata* was introduced through huge amount of imported fruits from infested countries like Egypt, South Africa and Israel (Salavatian and Sabzevari, 1975). It was spread quickly throughout some provinces with semi-cold climate conditions such as Azerbaijan, Esfahan, Yazd, Khorassan, Kermanshah and Tehran as well as east and central parts of Mazandaran province, with sub-mediterranean climate, which is the main place of mandarin varieties in northern parts of the country. Fortunately, shortly after identification and recognition of Medfly in infested areas, a serious integrated pest management control has been conducted by Iranian Plant Protection Organization with close collaboration with Plant Pest and Disease Research Institute, as well as the severe environmental conditions in winters, caused the disappearance of *C. capitata* in semi-arid and cold areas. Then, the importation of different fruits (i.e. apples, citrus and stone fruits) from infested countries was stopped in 1978. and eastern parts of Mazandaran province was the only infested place in the country; therefore, an integrated pest management programme involving, mass trapping technique, bait spray using protein hydrolysate and malathion insecticides, collection and destruction of various infested hosts, harvesting of all kind of fruits at the end of harvesting season was performed throughout the infestation area. Low population density of pest and less fruit infestation was the main results, which obtained in 1982. Finally, unexpected cold weather started from the mid-autumn of 1982 followed by a long-lasting winter seriously eradicated the Med fly population in Iran (Salavatian & Sabzevari, 1976; Sabzevari & Jafari, 1991). Approximately, 24 years later, Medfly was collected in fruit orchards of central parts of Mazandaran province. One year later, it occupied not only throughout the province but also other parts of country because of transportation of infested fruit to other provinces. Due to the modern horticulture industry, widespread planting of different host plants such as early ripening stone fruits, pome fruits, citrus varieties, *C. capitata* became a serious pest in Iran since 2008 (Mafi Pashakolaei, unpublished data).

Current control program of *C. Capitata* is mainly based on applications of organophosphate insecticides, especially Malathion mixed with protein baits (Khaleghii *et al*., 2010). However, the intensity of insecticide application with Malathion, chlorpyrifos-methyl, pyrethroid compounds (e.g. lamdda-cyhalothrin) and spinosad have induced the development of resistant populations. Moreover, these insecticides are controversial in worldwide concerning human health and the harmful effects on beneficial insects, activity and survival of natural enemies and non-target organisms (Flessel *et al*., 1993; Troetschler, 1983; Navarro-Llopis *et al*., 2004). The sensibility of the public opinion to environmental matters in the last decades, has led to the search for alternative control methods. Among the different techniques, mass trapping is a suitable method against some of the most damaging Tephritids, such as Olive fruit fly (Petacchi *et al*., 2003), *Anastrepha suspense* (Epsky & Kendra, 2016) and *C. capitata* (Alonso *et al*., 2002; Garcia *et al*., 2003; Demirel & Akyol, 2017).

Based on Sastre *et al.* (1999) mass trapping Medfly in infected areas has appreciably reduced the adult populations; More than 30000 ha of clementine groves are protected from Medfly by mass trapping (50 traps per ha) in Spain (Navarro-Llopis *et al*., 2008). The present work was aimed to assess the mass trapping approach based on Cera Trap and Trimedlure and to manage the Medfly as well as evaluation of its damage potential in the region.

Materials and Methods

The experiments were conducted during growing seasons of 2007 and 2008 at citrus orchards located in Sari, Mazandaran province, Iran. The main fruit variety of orchards was early ripening Clementine with few numbers of fig, persimmon and pomegranate trees planted at the edges. The orchards contained approximately 313 trees per ha (5×6m) with drip irrigation system. In 2007, a primary survey was carried out to evaluate the population trends of Medfly along with fruit damages to select an appropriate orchard to perform mass trapping approach in the following year. Two monitoring Delta traps (distance between 2 traps were 50 m) baited with Trimedlure (Russel IPM, Flintshire, United Kingdom) were set at a height of 1.5-2 m ground (1 ha) in the middle of September and checked weekly. Trimedlure dispensers of Delta traps were replaced every two months. To assess the fruit damages, 500 fruits were visually inspected on each sampling date randomly and the percentage of Medfly damage to fruits was recorded.

The mass trapping approach based on female and male-targeted attractants was carried in a citrus grove (1 ha which was selected in 2007) using Tephri-trap (with 250 ml Cera lure as a food attractant for females) and Jackson trap (baited with Trimedlure as a sexual attractant for males) and control plot (0.5 ha) in 2008. Cera lure (Bioiberica, Barcelona, Spain) is a liquid lure consisting of enzymatically hydrolysed proteins that released some volatile compounds, mostly amines and organic acids (Marin, 2010).

Distance between plots were more than 500 m. In total 98 traps (70 Tephri-traps and 23 Jackson traps) were installed and distributed on one-third of citrus trees in treated plots when the fruit colour started to change, almost one month before harvest (fig. 1). All traps were placed at a height of 1.5-2.0 m from ground, on the south part of tree, slightly inside of tree canopy. For each Jackson trap, almost three Tephri-traps were set (fig. 2). Monitoring of adult population of Medfly in the treated and control plot was performed by using two Delta traps per each plot. Tephri-traps were serviced once every two weeks and Trimedlure dispensers of Jackson traps were replaced every two months. The achievement of mass trapping technique was on randomly examining of 100 fruits every week from September until harvesting time (i.e. November). Data were analyzed by using SPSS ver. 16 (a paired t-test).

A. Jackson trap baited with Trimedlure

B. Tephri-trap baited with Cera lure

C. Delta trap baited with Trimedlure

Fig. 1. Trapping devices used in the field trials.

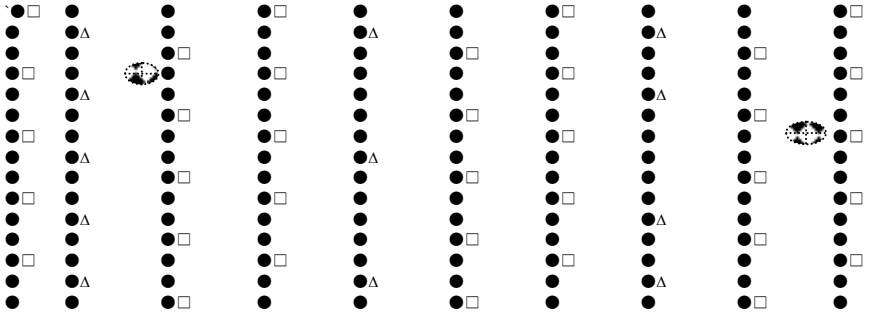

Fig. 2. The map of installed traps in mass trapping plot (shown only 0.5 ha), 2008. ● trees of garden, □ Tephri-trap, Δ Jackson trap, Monitoring trap (Delta trap).

Results

According to the mean number of captured flies by monitoring traps, population density of *C. capitata* was high in experimental orchard (Fig. 3). Pest population started to increase from the beginning of the study and reached the highest number (main peak) on the middle of October. The mean number of the pest population was determined as 60 flies/trap/week this period, remained in this level until early November and showed a decreasing trend in the following counts with 35 flies/trap/week in November. The capture of traps decreased gradually during harvest time and reached to the lowest level at the end of December. The first infested fruits were observed from late of September and increased slightly in October (Fig. 3). The highest percentage of infested fruits (an average 76%) was recorded at the end of November. Based on Medfly capture rate and high percentage of fruit infestation (in 2007), this citrus grove was chosen for mass trapping experimental field for 2008.

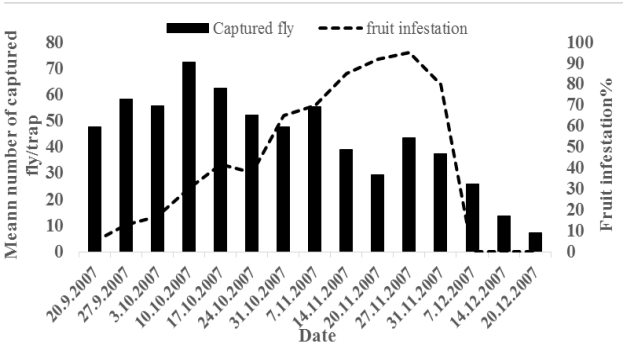

Fig. 3. Mean number of captured fly and fruit infestation (%) in experimental orchard in 2007.

Mean numbers of females caught per trap per week in Tephri-trap and average numbers of males capture per trap per week in Jackson trap in 2008 were tabulated in Table 1. Based on each kind of attractant in the traps, Tephri–trap and Jackson trap mainly captured females and male flies, respectively. Although the initial captures of adult flies were high, but continuously it decreased to lowest level at the end of December. Approximately 35010 females (38/trap) and 5320 males (17/trap) of *C. capitata* were captured by different traps in mass trapping plot during three months (24/09/2008-28/12/2008).

Table 1. Mean number (±SE) of female and male flies caught per week and per trap in mass trapping plot baited with Cera-trap and Trimedlure, 2008.

Date	Tephri-trap (n=70) (Females)	Jackson trap (n=28) (Males)	Total (n=98)
24/09/08	48.11±4.55	28.51±6.25	76.62±10.8
30/09/08	35.85±4.37	41.14±5.58	76.99±9.95
08/10/08	28.64±2.37	11.92±2.88	40.56±5.25
16/10/08	21.35±2.02	25.85±5.45	47.2±7.47
23/10/08	22.78±2.49	23.92±2.84	46.7±5.33
30/10/08	8.02±1.23	11.42±1.92	19.44±3.15
06/11/08	10.57±1.23	10.71±1.59	21.28±2.82
13/11/08	9.14±1.27	10.14±2.4	19.28±3.47
20/11/08	10.30±2.2	11.14±3.01	21.44±5.21
27/11/08	12.28±1.72	9.21±1.75	21.49±3.47
07/12/08	3.73±0.69	3.21±1.14	6.94±1.83
15/12/08	1.64±0.45	2.21±0.61	3.85±1.06
28/12/08	0.23±0.12	0.28±0.12	0.41±0.24

Population trends of male and female flies in mass-trapping shows that the average numbers of captured males and females per trap per day was rather high and gradually decreased during harvest time (Fig. 4.). Although the capture numbers of male pest in the first three sampling had some fluctuations, but in successive weeks until to the end of survey, the curves were very similar for both sexes in mass trapping plot, in 2008.

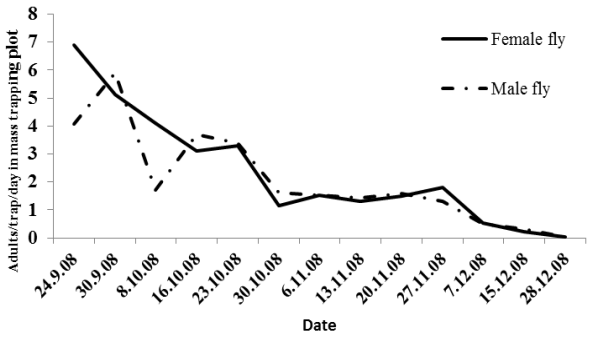

Fig. 4. Mean daily female and male captures per trap in mass trapping plot, 2008.

Data of monitoring traps in control and treated plot indicated significant differences between mean numbers of captured flies by Trimedlure in two plots (Table 2). In control plot, average number of flies in October was higher than other months. However, in mass trapping plot, average number of trapped flies in different months was very close to each other.

Fruit infestation started from the beginning of colouring and maturing of fruit and extended to harvesting time (Fig. 5). The proportion of damaged fruits was very low (approximately 0.5%) in mass trapping plot compared to control plot (almost 42%). The highest percentage of fruit infestations in control and mass trapping plot was 90% and 2%, respectively. There was a significant difference (P<0.0001, df=11, t=32.22) between fruit infestation to Medfly in treated and control plots.

Table 2. Mean number (±SE) of flies caught per week and per trap in control and mass trapping plot baited with Trimedlure, 2008.

Date	Control plot	Treated plot (mass trapping)
	Monitoring trap (n=2)	Monitoring trap (n=2)
24/09/08	35.75±3.03	19.51±3.52
30/09/08	40.25±4.41	21.14±4.87
08/10/08	51.00±5.56	8.18±2.36
16/10/08	60.25±4.61	17.23±3.92
23/10/08	68.00±5.35	18.42±4.26
30/10/08	43.75±3.04	7.25±2.16
06/11/08	42.01±2.11	11.16±3.94
13/11/08	36.25±3.25	9.74±1.97
20/11/08	58.2±3.22	8.45±2.25
27/11/08	37.25±3.19	7.62±1.56
07/12/08	29.50±2.36	2.54±0.82
15/12/08	20.0±3.41	1.13±0.21
28/12/08	11.25±1.23	0.28±0.13

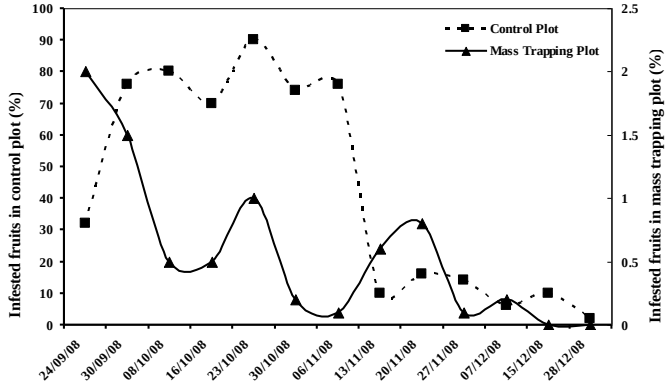

Fig. 5. Percentage of infested fruits by *C. capitata* in control and mass trapping plot, 2008.

Discussion

Several mass trapping systems with different male and female attractants have been developed to manage the *C. capitata* population in fruit orchards worldwide (Martinez, *et al*., 2011; Alonso & Garcia, 2013; Elekcioglu, 2019). In present study (2007), pest population was low at the beginning of September and steady increased from the middle of September and reached to the highest level in middle of October when the fruits colour started to change. Afterwards, pest population gradually decreased from early November and reached to lowest in late December, when the mean daily temperature decreased and fruits were harvested completely. There are several investigations in different countries on the population fluctuation of *C. capitata* in various fruit orchards with results shown similarities with our results. In this regards, Katsoyannos *et al*. (1998) in their study conducted in citrus orchards in Greece, determined the highest number of adults caught in traps were in October and November. Martinez *et al*. (2006) stated that the dynamics and abundance of *C. capitata* differs from orchards to orchards. In some groves population peaks only observed in summer and in other groves peaks only showed in autumn. Demirel and Akyol (2017) reported that pest population increased in October and November in a Satsuma mandarin orchard in Hatay, Turkey.

According to the results of present study, the total number of females captured by Tephri trap was nine times higher than males by traps lured with Trimedlure, although the number of female per trap was three times higher than male per trap. Trapping females is more important for *C. capitata* control management since the number of eggs laid reduce severely as well as fruit infestation. In this regard, Elekcioglu (2019) observed that the number of females captured in their study was three times higher than males, which related to pest population, host variety, traps, climate condition, etc. Satar & Tireng (2016) found out that the rate of male: female as 27%: 73% and 31%: 69% in their mass trapping study, where used three pack compounds (deltamethrin+ammonium acetate+chlorohydrate trimethyamine -diaminopentane) as food for female and Trimedlure for male in an Okitsu wase mandarin orchard.

The infested fruit of citrus in control plot (40%) was extremely higher than mass trapping (2%) plot in 2008. Martinez-Ferrer *et al*. (2012) reported that, application of mass trapping in an integrated pest management programme reduced the fruit damage to less than 2 % in early ripening citrus variety, as we stated in present study. In other study, Demirel & Akyol (2017) revealed 10.91% and 8.56% rate of

damaged fruits in Satsuma mandarin orchard in Hatay by applying 48 and 23 Eostraps per 0.7 ha baited with 95% Trimedlure, respectively.

Trap density and type of attractants are highly important for capturing a high number of females and male in mass trapping technique. Navarro-Llopis *et al*. (2008) found out 50 traps per ha are appropriate number traps for mass trapping in citrus orchards in Spain. Miranda *et al*. (2001) determined traps distance in grove almost 15 m apart with different traps and attractants, which meant setting one trap per 225 m^2. Navarro-Llopis *et al*. (2008) recommended increasing trap efficacy and less direct interaction, hanging the traps 20-25 m apart, which meant setting one trap per 400-625 m^2. Martinez- Ferrer *et al*. (2010) suggested a range of 25, 50, 75 and 100 traps per ha for different varieties. For the Clemenules variety, the number of 25 traps per ha were enough to capture adult insects within the grove. For early season ripening citrus varieties, the numbers of 50 traps per ha trapped as many as adults flying captured as 75 and 100 traps per ha, but not adequate to reduce the adult Medflies foraging in the grove under accepted levels. In this research, a mixed of food attractant of Cera trap (with 70 traps per ha) for female and Trimedlure (with 23 traps per ha) for male was highly effective on adult trapping and less fruit damage in early ripening Clementine variety.

In conclusion, taking into account that mass trapping is an effective control method against *C. capitata* in early ripening Clementine orchards that start to colouring by late of September. At that time, the pest population density is very high and less than 90 traps per ha is insufficient to ensure successful control of pest and fruit damage in citrus grove. According to the results of this study, we strongly recommend the 100 traps/ha (75 food attractant and 25 Trimedlure traps) to obtain superior result from mass trapping method in orchard.

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