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Population Dynamics of the Mediterranean Fruit Fly in Montenegro

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ABSTRACT: Population dynamics of the Mediterranean fruit fly was studied along Montenegro seacoast. Tephri traps baited with 3 component female-biased attractants were used in 11 different localities to monitor the fruit fly population in commercial citrus orchards, mixed-fruit orchards, and in backyards. From 2008–2010, the earliest captures were recorded no earlier than July. In 2011, the first adult fly was detected in mid-June. Low captures rates were recorded in July and August (below 0.5 flies per trap per day; FTD) and peaked from mid-September to the end of October of each year. Our results indicate fluctuation of fly per trap per day depending on dates of inspection and locality, with significant differences in the adult population density. A maximum population was always reached in the area of Budva-Herceg Novi with an FTD of 66.5, 89.5, 71.63, and 24.64 (from 2008–2011 respectively). Fly activity lasts from mid-June/early-July to end December, with distinct seasonal variation in the population.

KEYWORDS: Mediterranean fruit fly, Montenegro seacoast, population dynamic, FTD

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Introduction

The Mediterranean fruit fly, *Ceratitis capitata* (Wied.), (Diptera: Tephritidae), is one of the world's most damaging pests of fruits and vegetables. It is highly polyphagous and infests fruits of 374 species belonging to 69 families.[1] Mediterranean fruit fly originated in the tropical region of western Africa,[2] although as a cosmopolitan pest invaded all tropical and subtropical regions of the world[3,4] and even some temperate regions.[5]

Regarding tephritid fruit flies, Bateman[6] indicated that temperature has the dominant role in determining development rates and is responsible for the timing of the population processes and their synchronization with changes in the environment. In temperate climates, fruit flies are seasonal in abundance and multivoltine species, such as *C. capitata*, increase their numbers up to a peak in late summer and early autunm and then decline rapidly.

The phenology and population dynamics of *C. capitata* have been studied mostly in the tropics and less in temperate areas such as the northern, cold areas of its current geographical distribution.[7,8] Studies on the population dynamics of *C. capitata* have shown that the main factor affecting population build-up in the tropics is fruit availability and abundance, while in temperate areas of Europe it is low winter temperatures.[9,4,10,7] However, there is lack of data for populations from the northern coast of the Mediterranean basin.[11]

Although first monitoring of the Mediterranean fruit fly in Montenegro was in 1959, there is no precise data about its presence from that time. There were sporadic detections during 1980s and 1990s, and some recorded damage to mandarins (*Citrus reticulata*), although without any systematic data of its populations. The Mediterranean fruit fly has been considered an established pest in Montenegro since the early 2000s. Infested plants that have been detected since 2002 include mandarins (*Citrus reticulata*), oranges (*Citrus sinensis*), lemon (cultivar Lunario) (*Citrus limon*), grapefruit (*Citrus paradisi*), figs (*Ficus carica*), persimmon (*Diospyros kaki*), jujube (*Ziziphus jujuba*), and apples (*Malus domestica*).[12,13] Among these, in an economic sense, the most important is mandarin (cultivar Unshiu) that matures from mid-September to mid-November.[13]

The main objective of this study was to monitor the occurrence and population dynamics of *C. capitata* in Montenegro seacoast in a systematic way to provide baseline data to suppot the implementation of control measures.

Materials and Methods

Study area. The population dynamics of *C. capitata* was studied along 300 km Montenegro seacoast which lies along the Adriatic Sea, between 41° 52' and 42° 29' north latitude. The climate of this area is classified as Mediterranean with long, hot, and dry summers, relatively mild and rainy winters, and average annual air temperatures of approximately 15.8°C (http://www.climateadaptation.eu). The study was carried out from 2008–2011 in 11 localities. Localities were divided in three areas: Ulcinj (Darza, Gornji Štoj, Donji Štoj), Bar (Bar 1, Bar 2, Šušanj), and Budva-Herceg Novi (Lastva Grbaljska, Radanovići, Baošići, Đenovići, Kumbor) (Table 1). In the areas of Ulcinj and Bar, most commercial groves of mandarins exist and chemical control with cover sprays are used regularly. The area of Budva-Herceg Novi is composed mainly of mixed orchards and backyards where rarely control methods are used. Average monthly air temperatures for monitored period were obtained from Hydrological and Meteorological Service of Montenegro and are shown in Figure 1.

Fruit fly monitoring. For our study, Tephri Traps® (Sorygar SL, Las Rozas, Madrid, Spain) baited with 3 component female-biased attractant (ammonium acetate, trimethylamine, and putrescine)[14] from Suterra (Bend, OR, USA) and insecticide dichlorvos (DDVP strips) from AgriSense-BCS. Ltd. (Pontypridd, South Wales, UK) were used to monitor the population dynamics of *C. capitata* in commercial citrus orchards (mostly mandarins) which dominate in areas around Ulcinj and Bar, and in mixed-fruit orchards (mostly mandarins together with figs, persimmons, and sporadically apples, jujube, or peaches) and backyards in private houses (with several trees of different host plants) dominated in area of Budva-Herceg Novi. Eleven traps in total were set at 1.5 m above the ground on the south-eastern side of the tree.[15] Depending on the year, traps were set up from mid-May to mid-June and inspected every two weeks until the end of December.

Statistical analyses. Trap captures were expressed as the number of flies per trap per day (FTD). Total trap captures in different localities were tested using analysis of variance (MANOVA) for a completely randomized design, with two-factorial arrangement (trap captures expressed as FTD and dates of inspection). Means were separated according to the Tukey's honestly significant difference (HSD) test ($P = 0.05$).

Results

The average temperatures were similar for the three areas where the study was conducted for the four years (Fig. 1). A minimum of average temperature of about 5°C was measured in January–February and the highest average temperature of about 25°C was measured in July–August.

When analyzing the temperature for the four years of the study (Fig. 1), low variation was observed from year to year for area of Budva-Herceg Novi. The same is true for the other two areas.

In Figure 2, a diagram with the most important host plants of *C. capitata* and their ripening period in Montenegro is presented. Figs are the first available hosts and contribute for the Mediterranean fruit fly population increase in the summer months, causing economic damage later to mandarins, the most economic important host for *C. capitata* in Montenegro.[12]

Table 1. Study sites where Tephri trap with 3 component female-biased attractants for *Ceratitis capitata* were installed on the Montenegro seacoast.

AREA	LOCALITY	LATITUDE (NORTH)	LONGITUDE (EAST)	ELEVATION ABOVE SEA LEVEL (m)
Ulcinj	Darza	41° 56' 55.50"	19° 19' 12.78"	8
	Donji Štoj	41° 53' 15.50"	19° 21' 14.14"	3
	Gornji Štoj	41° 54' 28.15"	19° 17' 30.77"	5
Bar	Bar 1	42° 05' 09.90"	19° 06' 10.10"	8
	Bar 2	42° 05' 51.64"	19° 06' 14.95"	10
	Šušanj	42° 06' 43.53"	19° 05' 59.88"	30
Budva Herceg Novi	Lastva Grbaljska	42° 18' 25.17"	18° 48' 11.12"	15
	Radanovići	42° 18' 25.17"	18° 48' 11.12"	66
	Baošići	42° 26' 38.22"	18° 37' 53.20"	22
	Đenovići	42° 26' 19.77"	18° 36' 41.04"	26
	Kumbor	42° 26' 19.25"	18° 35' 53.80"	53

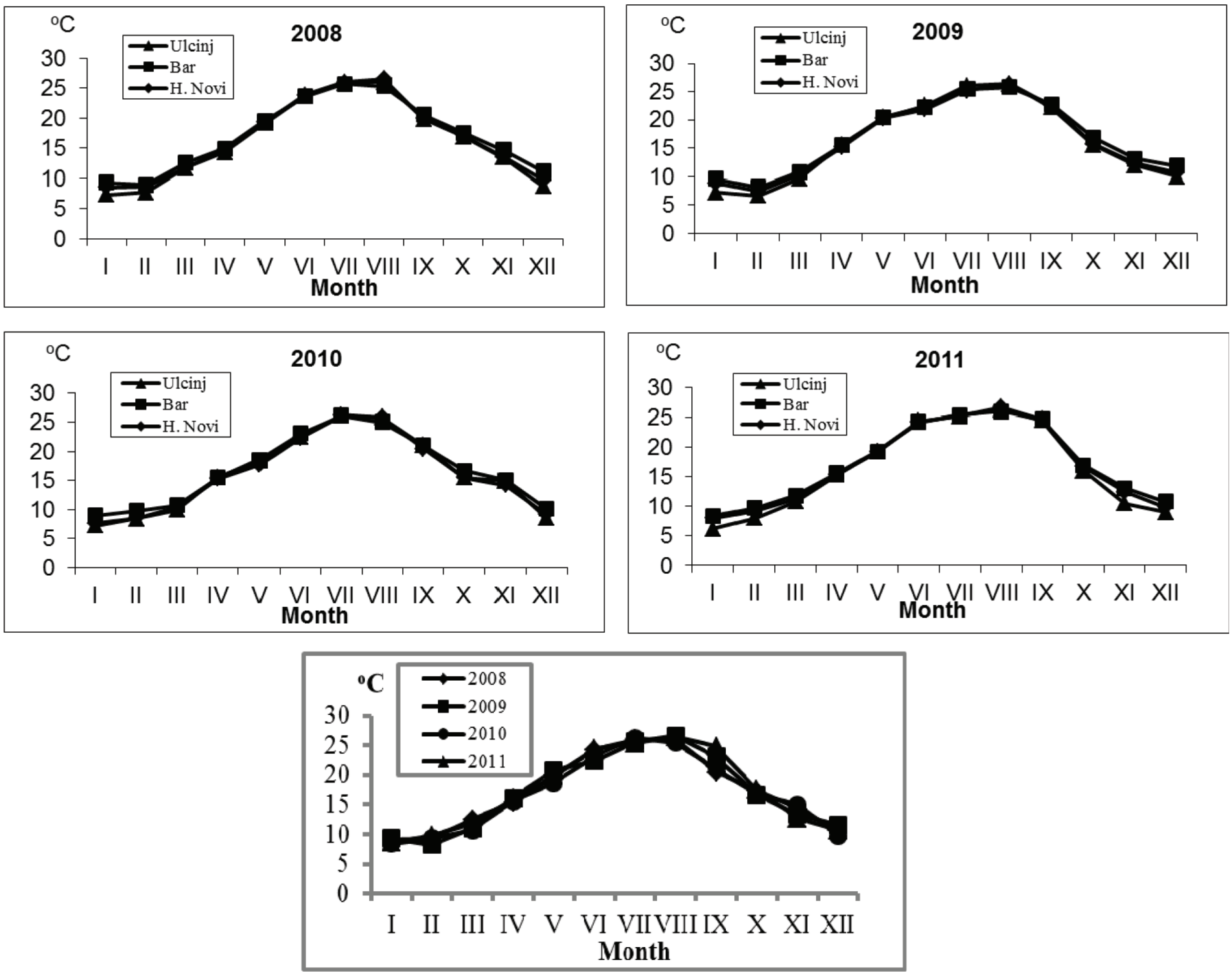

Figure 1. Average monthly temperature in the three areas of Montenegro seacoast (Ulcinj, Bar, and Budva-Herceg Novi) for the period of the study (2008–2011). The graph at the bottom of the figure shows the temperature for the period of the study in one of the areas (Budva-Herceg Novi).

Trap captures are presented in Figure 3. During the monitoring period (2008–2011) adults of *C. capitata* were detected in each of 11 localities within three surveyed areas.

Our results show that during 2008–2010 the earliest captures of adults (a single female in 2008 and 2010, and four females in 2009) were recorded in July in the localities of Đenovići, Kumbor, and Baošići (all in the area of Budva-Herceg Novi). The earliest adult captures (one female) during the entire monitoring period were recorded on June 19, 2011 in Kumbor. First records were always obtained in mixed orchards or backyards of private houses. In other localities, particularly in the areas of Bar and Ulcinj, where commercial citrus orchards dominated, the first captures were recorded later, in August, September, and even October.

Data for the four years of study, shown in Figure 3, indicate that after low adult capture rates in July and August each year, population density began increasing at the end of August and the beginning of September. A population peak

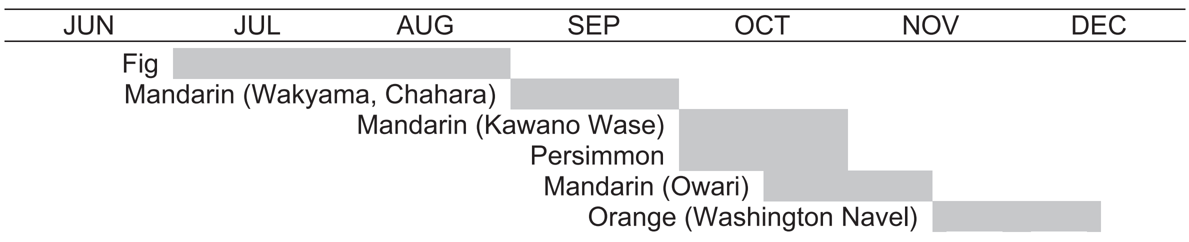

Figure 2. Seasonal *Ceratitis capitata* host availability and maturation period of the most important fruits in Montenegro seacoast.

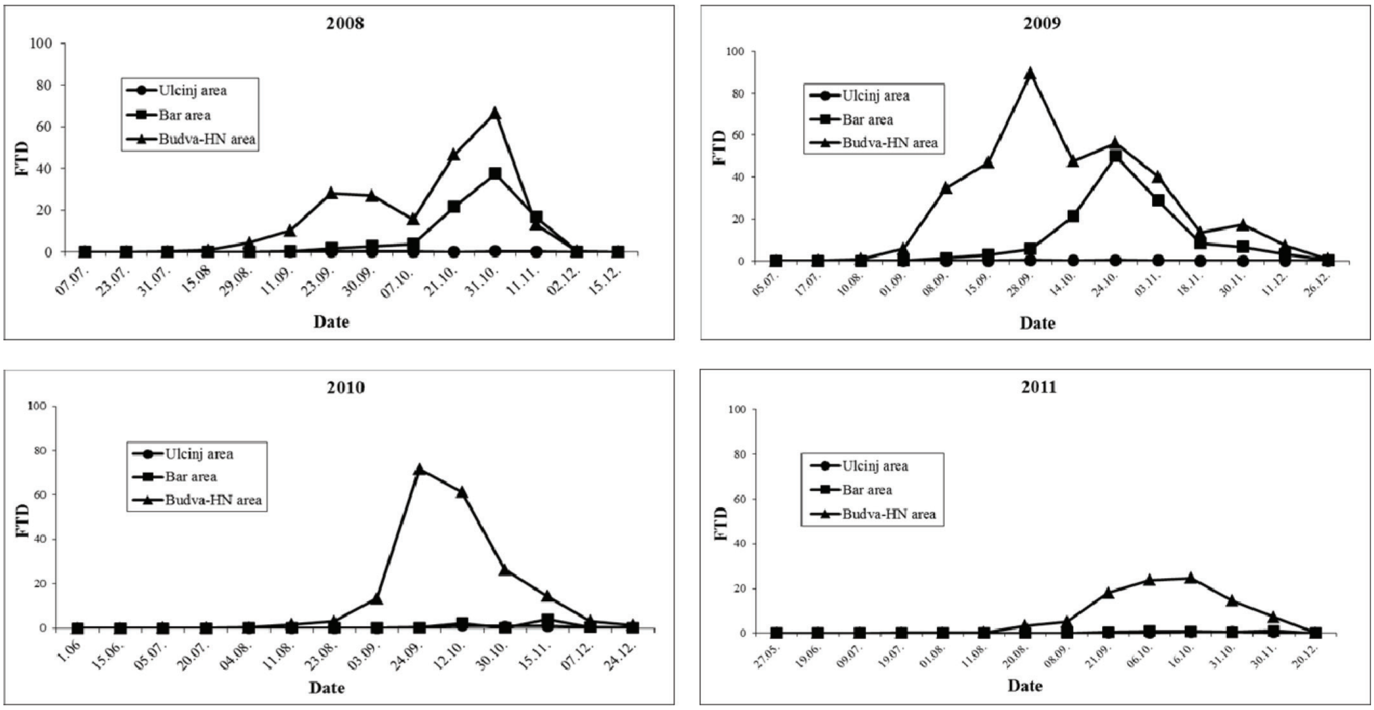

Figure 3. Captures in fly per trap per day (FTD) of *Ceratitis capitata* in the three areas of Montenegro seacoast (Ulcinj, Bar, and Budva-Herceg Novi) for the period of the study (2008–2011). Data obtained from the Tephri trap with 3 component female-biased attractants and inspected every two weeks.

was observed in the period from mid-September to the end of October in each year of the study. A maximum FTD value reached was of 66.5, 89.5, 71.63, and 24.64 in 2008, 2009, 2010, and 2011, respectively, in the area of Budva-Herceg Novi. Overall, the adult population began decreasing in November and the last flies were captured during the second half through the end of December.

Statistical analysis for a total of four years of trapping showed fluctuation of FTD values depending on locality, with statistical significant differences ($HSD_{0.05} = 11.28$) in adult population density (Fig. 4). Comparison of FTD means (Tukey's test) showed significant differences between Baošići and all other localities. Overall, a clear statistic difference can be observed between the localities of the area of Ulcinj (with low total captures) and the other areas.

Discussion

The results of our study show that in Montenegro seacoast *C. capitata* has a distinct seasonal occurence of population fluctuations. Adults were detected from the end of June and captured until the end of December. After the first detection of the season, population density was very low in July and August and the number of captured flies increased slowly during August and the first half of September. Each year, the population peaked from mid-September through the end of October. Regarding a seasonal variation in the population dynamics of *C. capitata*, our results are similar to the data presented by Papadopoulos et al[7] in the area of Thessaloniki, Bjeliš et al[16] in Croatia and Escudero-Colomar et al[17] in the north-eastern region of Spain. These locations, as well as the Montenegro seacoast, are close to the northern limits of *C. capitata* distribution in Europe, although Rigamonti[18,8] revealed information regarding the fly biology and overwintering in northern Italy, which lies even more northern (Milan, Lombardy, approximately 45° north latitude).

Our data showed that over the entire study period, population peaked within the average monthly temperature of 21.9°C in September and 16.2°C in October (averages for 2008–2011), which is similar to data presented by Papadopoulos et al[7] for Thessaloniki, Greece (40° 38' 25" north latitude).

Nevertheless, it can be also concluded that population dynamics of *C. capitata* are influenced by host fruit availability and abundance. The sequence of available host plants that increased from September and October resulted in a distinct and large population increase. Bjeliš et al[16] showed that seasonal outbreak in Croatia could be explained with the figs and peach ripening period, as those two host plants are important for the new generation's outbreak starting from September.

The seasonal occurrence of *C. capitata* on the island of Chios (Greece), which is located in the more southern area of the country (approximately 38° north latitude), also shows certain similarities with patterns presented for the Montenegro seacoast, region of Thessaloniki, Croatia and north-east of Spain with very low captures in June and July, December and January, high from August to November, and the absence of flies from February through May.[19] According to these authors, *C. capitata* population parameters in Chios are substantially influenced by hosts and abundance appears to be

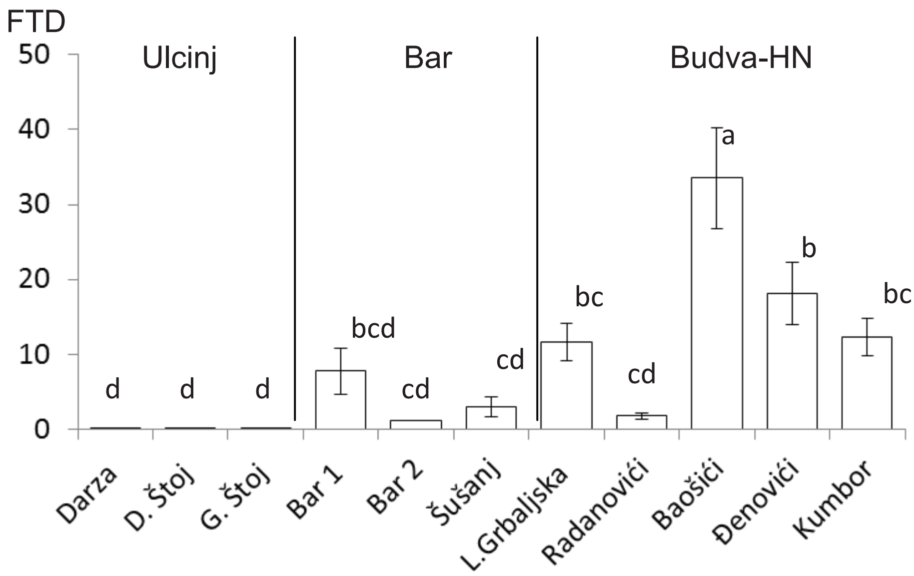

Figure 4. Average captures in fly per trap per day (FTD) of *Ceratitis capitata* at the 11 sites of the Montenegro seacoast for the period of the study (2008–2011). Data obtained from Tephri trap with 3 component female-biased lures and inspected every two weeks. Bars present standard error (over the years of the study) and different letters represent significant statistical differences between averages of the 11 traps (Tukey's HSD test ($P = 0.05$)).

closely associated with the seasonal maturation of the most important hosts in the region. Host plant availability, as well the presence of preferred hosts, creates large amounts of variation in *C. capitata* abundance. This importance is related with the host ripening sequence and fruit availability.[20]

Regarding the Montenegro seacoast, the absence of spring and early summer host plants, together with decreasing of the average monthly temperature in December and particularly in January, could be considered as determining parameters for the *C. capitata* adult activity.

Over the period of the present study, the area of Budva-Herceg Novi was ranked as the point of the earliest and highest adult captures every year. The main reason which could explain this population abundance is the absence of commercial fruit producing areas and the existence of abundant mixed orchards, and backyards with several host trees, so growers usually do not apply control measures, either cultural or chemical. As it is a residential and tourist area, growers avoid using chemical control. Moreover, growers traditionally do not spray figs and persimmons along the whole seacoast and these hosts are particularly important in summer and early autunm for breeding of the fly, and consequently large population build-up in September and October.

Later appearence of the fly in areas of Bar and Ulcinj, followed by lower capture rates, could be explained by the fact that those are the most important mandarin producing areas in Montenegro where the biggest commercial orchards are placed and producers regulary apply control measures. Those control measures include some sanitation and insecticide cover spray and can contribute to the maintenance of the population at low levels during the summer period.

Conclusion

The results obtained in this four-year study suggest that along Montenegro seacoast, which is located close to the northern limits of *C. capitata* distribution in Europe, the fruit fly has distinct seasonal patterns in population fluctuation. Population density is very low during July and August, increases during August and first half of September, and peaks from mid-September to end of October. Adult activity ends in December.

We also observed that population dynamics of *C. capitata* are closely linked with host fruits' availability and abundance. As the sequence of suitable host fruits increased during September and October (different mandarin cultivars, persimmon), it resulted in large population build-up.

Our results also indicated fluctuation in FTD depending on date and locality, with significant differences in adult population density.

Preliminary results of the present study, together with data from other studies obtained from places within the northern limit of *C. capitata* establishment in Europe, show the need for further investigation regarding its biology, overwintering, and behavior on the Montenegro seacoast, particularly the relationship with the hosts' availability and abundance, based on geographic distribution to be integrated with climatic data and develop predictions of the population dynamics.

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Author Contributions

Conceived and designed the experiments: SR. Analyzed the data: SR, MČ, RP. Wrote the first draft of the manuscript: SR. Contributed to the writing of the manuscript: RP. Agree with manuscript results and conclusions: SR, MČ, RP. Jointly developed the structure and arguments for the paper: SR, MČ, RP. Made critical revisions and approved final version: RP. All authors reviewed and approved of the final manuscript.

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