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Host Interaction and Population Dynamics of *Ceratitis capitata* in Agroecological Systems: Level Infestation in Key Hosts in Irrigation Oasis of San Juan, Argentina

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Abstract

This study focuses on the infestation and abundance of *Ceratitis capitata* (the Mediterranean fruit fly) in various host fruit species in San Juan, Argentina, where agriculture plays a key role in the local economy. The aim of the study was to determine the percentage of infestation and the abundance of pupae in different host species, including peaches, nectarines, plums, apricots, and figs. The results showed significant variation in infestation rates and pupal abundance across the different host species. Peaches, particularly the flat peach variety, showed the highest infestation rates and pupal abundance. Figs also contributed significantly. Infestation levels were highest in the early stages of peach fruit ripening and decreased once peaches were no longer available. Peach varieties, especially flat peaches, were the primary hosts responsible for maintaining *C. capitata* population. Figs played an important role as well, while plums and apricots were less significant. The findings support the idea that peaches and figs act as a key hosts in this region, similar to results from previous studies, suggesting the importance of these crops in controlling the fruit fly population. Further studies over a longer period could provide deeper insights into the pest's behavior and control strategies.

Keywords: *C. capitata*; Fruit Fly Population; Pest-Host Interaction

Abbreviations

IPM: Integrated Pest Management; SIT: Sterile Insect Technique.

Introduction

Fruit flies are considered one of the most important invasive pests due to the significant losses they cause in fruit and vegetable production and the major impact it has on exports [1].

Ceratitis capitata, also known as the Mediterranean fruit fly, belongs to the order Diptera and the family Tephritidae. It is a species native to West Africa, which, due to a combination of factors such as various human activities, favorable climatic conditions, and the presence of host species, has spread across most countries in the Americas and worldwide [2].

San Juan, Argentina, is characterized by extensive agricultural valleys in irrigation oases, with a total cultivated area of 104,705 hectares. The local economy relies heavily on agro-exporting, with vineyards, olive groves, vegetable, and fruit crops standing out. Fruit production ranks fifth nationally in cultivated area, but it faces challenges due to the presence of the Mediterranean fruit fly, which causes significant yield losses and leads to quarantine restrictions for export markets. Since 2003, the Fruit Fly Control and Eradication Program (ProCEM) has implemented Integrated Pest Management (IPM), emphasizing the Sterile Insect Technique (SIT) as a primary tool, alongside chemical, mechanical-cultural control, and phytosanitary barriers. This strategy achieved a 79% reduction in the pest population by 2014. However, control remains insufficient in small family plantations, challenging the complete eradication of the pest in the province.

The Mediterranean fruit fly can infest a wide range of fruit hosts in an agroecological environment, categorized as "key" and "non-key" hosts based on their interaction with various fruit species and population fluctuations of the pest. Major key hosts include citrus fruits (excluding lemon and lime) and stone fruits, such as peach, apricot, and plum. The diversity of host species provides a sequential fruiting pattern throughout the year, allowing the fruit fly population to persist even under less favorable climatic conditions.

The host selection by *C. capitata* depends on factors such as the fruit's ripeness during the oviposition period and the abundance of other available hosts. This behavior is complex, involving a dynamic hierarchy where certain fruits are prioritized based on their availability and the presence of more attractive host species. Additionally, the preference may vary according to the physiological state of the individual, such as its egg load, and previous experience with alternative hosts when preferred ones are unavailable [3].

Nutritional levels in the fruits play a significant role in the larval development of *C. capitata*, as fruits with higher protein content, like fig, peach, and orange, support faster larval development and produce larger individuals. In contrast, fruits like apple are less favorable, resulting in slower development and higher larval mortality [4].

The aim of this study was to determine the infestation percentage and pupal abundance of *Ceratitis capitata* in host species during the summer season in an orchard with different key and non key hosts available, evaluating their impact on pest population dynamics and contributing to the optimization of management strategies in agroecological systems in an irrigation oasis.

Materials and Methods

Study Area

The sampling for this study was conducted on a family orchard located in the Department of Chimbas, San Juan, Argentina. This orchard includes key fruit species that attract *C. capitata*, making it a small-scale model for pest-host interaction. It covers an area of approximately 0.5 hectares, with various summer fruit species, primarily peach (*Prunus persica*), nectarine (*Prunus persica var. nucipersica*), flat peach (*Prunus persica var. platycarpa*), apricot (*Prunus armeniaca*), plum (*Prunus domestica*), and fig (*Ficus carica* 'Mission') (Table 1). Additional pome fruit species (non-key hosts) include persimmon (*Diospyros kaki*), apple (*Malus domestica*), pear (*Pyrus communis*), and kumquat (*Fortunella margarita*).

In San Juan, peach varieties have an early ripening period, beginning in November and extending through December [5,6]. Nectarine ripening occurs later, from December to March [7], although sub-varieties such as 'Aniversario INTA' and 'Caldessi 2000' ripen in December [5]. Apricots generally mature from mid-November to mid-February. For plums, San Juan typically cultivates varieties that ripen from November to early December, as well as late-maturing types from late January to mid-March [6]. The fig season starts in January and extends through early February [8], though some San Juan varieties can extend ripening through May.

Variations in the ripening times of different host species resulted in changes in the availability of mature fruits over the collection period. During all sampling sessions, persimmon, kumquat, pear, and apple trees did not produce mature fruits. Some plum and fig plants (various varieties) had interrupted fruiting, resulting in periods without mature fruits in certain collections. The orchard was not subjected to any pest control management for at least two years prior to and during the study, ensuring that the fruit trees were untreated with insecticides.

Host Species	Number of Trees	Sampled Trees
Apricot	5	5
Fig	6	6
Plum	20	20
Common Peach	31	25
Nectarine	10	10
Flat Peach	11	11
Total	90	77

Table 1: List of hosts found on the orchard.

Experimental Design

The species richness and abundance of each host species present in the orchard were recorded. Four collections (sampling sessions) were carried out every 15 days during December and January.

The sampling method used was stratified random sampling. Homogeneous strata were determined based on the sampling units present, which were then randomly selected. Each host species was considered a separate stratum. The number of strata from which samples were taken varied depending on the number of host species with mature fruits at each sampling session. To determine the number of sampling units within each stratum, a proportional allocation of samples was performed, assigning to each stratum a number proportional to the total number of plants present in it [9]. All samples collected were transported to the Plant Protection Laboratory, INTA San Juan Agricultural Experimental Station.

Infestation Percentage

The sampling was carried out within each stratum by selecting a number of trees proportional to the total number of trees present in the stratum. From each of these trees, 10 fruits were collected that showed no signs of infestation (such as aesthetic damage by decomposition, oviposition marks, and/or skin ruptures) [9].

To determine the infestation percentage, the 10 fruits from each host species were placed in individual containers with a layer of sterilized sand, which was used by the larvae as a pupation substrate. Once a week, during three consecutive weeks, the sand in each container was sifted to recover pupae, and the presence or absence of pupae was recorded. The infestation percentage for each host species was calculated as follows:

% Infestation = (Number of infested fruits / Number of fruits examined) × 100

Pupal Abundance

To determine the pupal abundance per host species in each homogeneous stratum, trees were selected at random, and 15 fruits with evidence of infestation were collected, ensuring that none of them showed signs of larvae having exited the fruit.

The 15 collected fruits from each host species were weighed and placed in acrylic boxes with sterilized sand as a pupation substrate, under 25 ºC and 50 % relative humidity. The sand was sifted every 3 days, and the number of pupae present in each sample was recorded. The samples were discarded after five consecutive inspections in which no pupae were found. Pupal abundance was determined using the following formula:

Pupal abundance = (Number of pupae / kg of fruit)

Data Analysis

To evaluate the effect of the host on fruit infestation, a Generalized Linear Model with a binomial response variable was used. This choice was based on the fact that the response variable, infestation, takes two possible values: 1 (infested) and 0 (not infested). The explanatory variable was the categorical variable "host," with six levels, leading to the design of a one-way ANOVA. The logit link function was used [10]. The model was implemented using R software version 4.0.0.

To analyze pupal abundance, descriptive analysis was performed using the software Infostat/Student version, 2008. Appropriate measures of central tendency and dispersion were calculated, allowing for a correct interpretation of the situation under study. A significance level of 5% was used.

Results and Discussion

During the first sampling, a total of 160 fruits were harvested from the following hosts: common peach (CP) = 60; flat peach (FP) = 10; nectarine (N) = 30; apricot (A) = 10; plum (P) = 50; fig (F) = 0. Of these, 81 fruits were infested (CP = 44; FP = 9; N = 21; A = 4; P = 3; F = 0).

For the second sampling, 160 fruits were collected from the following hosts: CP = 60; FP = 40; N = 30; A = 20; F = 10. A total of 132 fruits were infested (CP = 48; FP = 39; N = 29; A = 16).

In the third sampling, 70 fruits were harvested from the following hosts: P = 40 and F = 30, with 50 fruits being infested (P = 29 and F = 21).

For the fourth and final sampling, 50 fruits were harvested, 30 of which were plums (P = 30) and 20 were figs (F = 20). The total number of infested fruits was 13, all belonging to the fig host (F = 13).

Table 2 shows the infestation percentages for each host in each sampling. The total infestation percentage was above 50% in all sampling, with at least two to three hosts contributing to the total infestation, while for the last sampling, only fig contributed to the infestation which was less than 30%. The plum presented available fruits, but no infestation was recorded.

Hosts	1st Sampling Dec 1 (n=160)	2nd Sampling Dec 17 (n=160)	3rd Sampling Jan 15 (n=70)	4th Sampling Jan 27 (n=50)
Common Peach	27.5	30	-	-
Flat Peach	5.6	24.4	-	-
Nectarine	13.1	18.1	-	-
Apricot	2.5	10	-	-
Plum	1.9	-	41.4	0
Fig	-	0	30	26
Total Infestation	50.6	82.5	71.4	26

Table 2: Infestation Percentages for each host by sampling date.

Host showed that they significantly contribute to the infestation, with the greatest contribution coming from the different peach varieties and the least from the plum (Table 3).

Host	First sampling			Second sampling			Third sampling			Fourth sampling		
	E	SE	p	E	SE	p	E	SE	p	E	SE	p
Common Peach	3,78	0,66	<0,0001	1,386	0,322	<0,0001	-	-	-	-	-	-
Flat Peach	0,57	1,21	0,634	2,277	1,063	0,032	-	-	-	-	-	-
Nectarine	3,61	0,71	<0,0001	1,981	1,067	0,063	-	-	-	-	-	-
Apricot	2,36	0,87	0,007	0	0,645	1,000	-	-	-	-	-	-
Plum	-2,77	0,59	<0,0001	-	-	-	0,96	0,354	0,006	-20,5	3237	0,995
Fig	-	-	-	-18,9	1,251	0,987	-0,12	0,533	0,818	21,19	3237	0,995

Table 3: Generalized Linear Model of Binomial Response for the Effect of Host on Infestation. E (Estimator), SE (Standard Error), p (Significance Value)

In the first two samplings, various peach varieties were available; they were preferred by *C. capitata* ovipositions since then contributed considerably to the infestation, while plum and fig (first and second samplings, respectively) contributed the least. Host availability explained 33% of the variation in infestation for the first sampling and 51% for the second one. On the other hand, in the third sampling, the plum and fig contributed similarly to the infestation, while in the final sampling, the variation in infestation was explained by 55%, with only the fig contributing to the infestation.

Figure 1 shows the pupal abundance per kilogram of fruit for each host during the different samplings. In each sampling, only those fruits that were mature were harvested. In the first sampling, flat peach showed the highest abundance, with 125 pupae/kg, while the lowest abundance was for plum, with 2 pupae/kg. During the second sampling, the number of pupae increased considerably for all hosts, with the highest number again recorded for flat peach at 558 pupae/kg, and the lowest number for apricot, with 211 pupae/kg. In the third sampling, only two hosts showed available fruit, fig and plum. In the final sampling, only the abundance of fig was recorded, with 336 pupae/kg. Although plum had fruit available, no pupae were found (0 pupae/kg). As shown in Figure 1, the highest number of pupae was recorded in fig, while the lowest was recorded in plum.

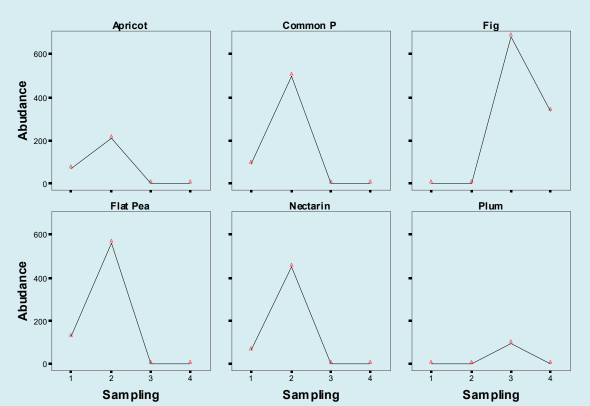

Figure 1: Abundance (pupae/kg) during the four sampling dates (December-January).

The hosts that showed the highest percentage of infestation also showed the highest pupal abundance. In this way, all the peach varieties were the most selected by *C. capitata*, even when mature fruits from plum and fig were available.

On the other hand, as the availability of peach and nectarine disappeared, the percentage of infestation and pupal abundance increased in plum and fig.

These results align with the Segura, et al. [9], which identified peach and all its varieties as a key host, being the one that contributed the most to the pupae population. On the other hand, fig, also a key host, contributed fewer pupae during the sampling period, although was important at the third sampling.

This study, on a very small scale, supports the findings and analysis by Segura, et al. [9]. Their study mentions that peach exhibited key host behavior, as it was responsible for increasing the population of *C. capitata*. Although this study did not aim to measure wild populations of *C. capitata*, it can be inferred that peach exhibits the same key host behavior, as it recorded higher infestation and pupal abundance compared to other hosts. The fig also contributed, thus inferring that it would be the second host most responsible for maintaining the fly population in the orchard.

Concluding Remarks

On the infestation results, which provide an estimate of the preference of female fruit flies for certain hosts, along with the abundance results, suggest that the different varieties of peach, and fig, were the key hosts of C. capitata during the sampled period and in relation to the other fruit species present in the study area. However, some limitations of this study suggest that this kind of research could provide further insight into the population dynamics by monitoring the C. capitata populations over a longer period, simultaneously with the infestation of all hosts, as well as conducting chemical studies of each host.

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