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Fruit fly (Diptera: Tephritidae) monitoring in a monospecific and biodiverse productive system of feijoa (*Feijoa sellowiana*) †

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Abstract: Feijoa (*Feijoa sellowiana* [Berg] Burret) has been cultivated in both agroforestry and monoculture systems in the southern region of Brazil. However, little is known about the occurrence of pests related to this culture in such region, especially in agroecological production systems. Within the economical relevant insects, fruit flies (Diptera: Tephritidae) occupy a concerning status to many producers. In this context, we aimed to monitor the presence of tephritides in *F. sellowiana* fruits produced under two different agroecological conditions, a monospecific cultivation and an agroforestry system. It was installed 30 traps on *F. sellowiana* trees, and their content collections executed every 10 days during the fructification period of 2019/2020 harvest, when it was also removed fruits to monitor the fruit fly's larva. Additionally, it was measured the parameters related to plant height, crown and trunk tree circumferences, as well as the plant productivity. In total, 1805 individuals were collected from the fruit fly traps, with a higher occurrence in the monospecific cultivation. It was observed a sexual ratio of 3.74 females for 1 male. About the larval monitoring, the infestation index was 11.86 pupae/fruit to the agroforestry system and 15.4 to the monospecific one, with a pupal feasibility of 25.84 % and 11.26 % to these areas, respectively. It was not observed statistical significance in relation to plants size parameters and occurrence of fruit flies in the monitored areas. In general, was observed lowest occurrence of fruit flies in the agroforestry system, suggesting the viability of cultivating feijoa in biodiverse systems.

Keywords: Feijoa; traps; massal capture; *Anastrepha*

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1. Introduction

A shrub species native to southern Brazil, the mountain guava *Feijoa sellowiana* (O. Berg) is synonymous with *Acca sellowiana* [(O. Berg) Burret], in addition, it has been managed and cultivated by small farmers in the region of occurrence, and its distribution follows mostly the Araucaria forest (Mixed Ombrophilous Forest) [1]. It was identified that, in addition to market opportunities, there is also genetic diversity, technical-scientific and local knowledge associated with species in the mountainous region of SC, suggesting that there is potential for the development of this culture, mainly for food purposes [1]. When it comes to research for the development of cultivars adapted to the state of Santa Catarina and with desirable agronomic characteristics, some institutions such as EPAGRI (Agricultural Research and Rural Extension Company of Santa Catarina), UDESC (University of the State of Santa Catarina) and UFSC (Federal University of Santa Catarina) has made research efforts in recent decades; however, additional research on cultural management, harmful insects and diseases for agroecological cultivation is still needed [2].

There are different ways of growing mountain guava following an agroecological approach, ranging from a gradient of a monospecific system established in an orchard to a biodiverse production model, such as the Agroforestry System. Biodiverse agroforestry systems, from the point of view of production systems, are those most similar to natural ecosystems in terms of ecosystem services and biodi-versity conservation, as they aim at the consortium of species with distinct ecosystem and economic func-tions. However, regardless of production systems, one of the greatest difficulties for the cultivation of *F. sellowiana* is the occurrence of harmful insects, including the fruit fly (Diptera: Tephritidae) [2].

In the case of *F. sellowiana*, its fruits are primary hosts of the fruit fly during the period from February to April, when it comes to its maturation [3]. The damage can reach 100 % of infestation, and this intense attack must possibly be due to the substrate considered ideal for the development of this group of harmful insects, and the presence and release of volatiles characteristic of the fruits during the period of maturation [4–7]

In order to make decisions regarding the control of fruit flies, it is first necessary to obtain information about the population levels of these insects in the area, and its monitoring is necessary. Through monitoring, it is possible to understand the real population dynamics of this harmful insect in each production system and, thus, analyze alternatives aimed at controlling the area [8]

To monitor fruit flies, the use of traps is essential. Among the traps, two models stand out, Jackson and Mcphail. Focused more on collecting males of *Ceratitis capitata*, the Jackson trap uses trimedilure para-pheromone as an attractant and has been basically made with paraffin cardboard. On the other hand, the McPhail trap is considered the standard for collecting *Anastrepha* adults, but it is important to emphasize that it is also possible to collect other insects, including *C. capitata*. In addition, on a commercial scale, it is the most used type of trap, which can be made using several alternative models, such as a PET bottle, or even a glass container. Among the most used food attractants, hydrolyzed proteins, 25 % grape juice and the Cera Trap® attractant stand out [5,9]

The capture monitoring strategy allows estimating population density. Population density, as well as host availability, are very important biotic factors that influence the population dynamics of different spe-cies of fruit flies in Brazil [10]. The highest pop-ulation density is linked to the ease of oviposition and feeding, resulting in high infestations [11].

There is little research in the region of Curitibanos regarding the behavior of fruit flies (Diptera: Tephritidae) in mountain guava crops, especially when they are arranged in SAF with agroecological management [2,3]. As this is an insect with the potential to damage up to 100% of the fruits, directly affecting the final quality of the fruit, it is essential to understand its behavior [7,12]. In addition, there is still no record of conventional phytosani-tary product for the control of this insect in mountain guava [2], which demonstrates the need to deepen alternative management and production strategies such as mass capture from traps. Thus, this work aims to expand information on cultivation, especially those that can contribute to the strengthening of agro-ecological agriculture.

2. Methods

The study was carried out in two areas located in the city of Curitibanos, SC. The first is the Didactic Area with Agroforestry System (SAF): Implemented 2012/2013 in the Legal Reserve area of the Campus Sede (27 ° 16'22.44 ″S 5 ° 30'11.50″ W), the site is enriched by species of ecological / economic interest. The second area, however, no less important than the first, is the Agricultural Experimental Farm (FEA): Collection of *F. sellowiana* genotypes, implemented in 2012–2013 and has an approximate area of 2,800 m² (27 ° 17'12.0 ″ S 50 ° 31'53.1 ″W). It is noteworthy that both areas aim at agroecological management. Fifteen plants kept in an agro-ecological agroforestry production system (SAF) (biodiverse system) and 15 plants in an established orchard production system (BAG) (monospecific system) were evaluated. Plants were identified and chosen at random

2.1. Evaluation of Mountain Guava Specimens

Height, crown and trunk circumference parameters were measured for the 30 plants monitored in the experiment. All measurements were taken at the end of the vegetative growth cycle and the data were submitted to the t test with 95 % confidence

2.2. Notes for Individual Production

A production-related visual score was applied to each plant during the fruiting period, with the score of 10 applied to the plant with the highest number of fruits, and the other plants were rated by applying a scale. comparison of the number of fruits with the first plant [4].

2.3. Monitoring of Adult Fruit Flies

Traps containing the food attractant Cera Trap® were installed on 07/01/2020 in all 30 plants (15 of each treatment) with one trap per plant, which was verified and accounted for the number of flies every 10 days during the fruiting period. The trap, made with 510 ml pet bottles, had three 1x2 cm openings. In addition, all bottles were painted yellow to increase their attractiveness. Every 10 days, the insects were collected, placing them in a flask containing 70 % alcohol, and later sent to the laboratory for screening and identification.

2.4. Larval Monitoring of Fruit Flies

One fruit per plant was collected, weighed and placed in a plastic container with a capacity of 35 liters with a layer of approximately 2 cm of vermiculite. The fruits of each evaluated area were kept at room temperature, separately, for a period of 15 days, so that the larvae, if present in these fruits, migrated to the vermiculite in order to proceed to the next stage of their life cycle, pupa. After 15 days, the number of pupae of fruits from the biodiverse and monospecific system was quantified. In addition, the identification of the genera of the specimens that hatched from these pupae was carried out, to confirm the fruit attack by the fly.

2.5. Identification of Collected Specimens

For the identification of specimens, the criterion used was the fact that the specimen had the largest and most extensive ovipositor being female, as it oviposites, and the others with an absent ovipositor were considered male. Furthermore, for identification, the insects were separated by the pattern of stripes and wing spots. Due to the limitations of the team's joint work in the laboratory, given the restrictions resulting from the pandemic, preliminary identifications were carried out with the aid of photographic records, which prevented further identification of the samples at the species level.

2.6. Data Analysis

For the quantitative data related to the plant, the Standard Deviation (SD) and also the F test were calculated, being subsequently submitted to the Student t test at 5 % significance if necessary.

To assess the correlation between climatological data and population fluctuation, climatological data from the INMET of the Climatological Station in the city of Curitibanos were used, subsequently submitted to correlation analysis with the help of the Excel computer program. To determine the coefficient of determination (r^2), the correlation coefficient was squared. The r^2 varies between 0 and 1, indicating the percentage of how correlated the observed values are [adapted from: 7].

The level of infestation 1 was calculated through the average number of puparia divided by the kilo of the fruit [13–14]

Infestation level 2 was calculated using the average number of puparia divided by the analyzed fruit units [adapted from: 7].

Pupa viability was calculated by the number of emerged flies dividing by the number of pupae and multiplying by 100 thereafter.

For the spatial analysis of the captured fruit flies, geostatistics was performed using Inverse Distance Interpolation (IDW) performed in QGIS software version 3.10.9.

3. Results

3.1. Evaluation of Copies of Feijoa

Only for the trunk circumference variable, the mean of the plants present in the FEA differed statistically, having 0.35 meters in contrast to the 0.27 meters of mean circumference of the plants in the SAF area. In Graph 01, it is possible to observe the distribution of data as a function of trunk diameter classes.

3.2. Identification of Fruit Fly Samples

To identify the captured insects, it was necessary to consider that *Ceratitis capitata* (the only species of the genus present in Brazil) has a smaller body size, and during the entire period of collection only one specimen of the female of *C. capitata* was collected. As for the genus *Anastrepha*, which has among its characteristics greater body size when compared to the other genera, a characteristic that facilitates identification, 380 males and 1424 females were collected, totaling 1,804 individuals.

3.3. Fruit Flies Monitoring

In the SAF area, 251 specimens of the genus *Anastrepha* were captured, between males and females, and its distribution, when analyzed separately, was 210 females against 41 males, resulting in a proportion of 5.12 females per male of flies. of the fruits collected in the traps. On the other hand, in the FEA area, the total number of specimens captured is 1554 specimens of fruit flies, being 1214 females and 339 males of *Anastrepha* (ratio of 3.58 females / male), with only 1 C. female capitate.

By analyzing the spatial distribution of the number of specimens collected, it is possible to observe that there was a lower incidence of fruit flies in the traps placed in the center of both areas. In addition, there was greater capture at the edges of the areas.

Regarding precipitation (mm), the correlation for SAF and FEA was positive, but weak and moderate, respectively. For the others, in general, the correlation was weak and negative for both areas. In SAF and FEA, precipitation influenced about 1.2 and 13.7 % in population fluctuation, according to the coefficient of determination.

3.4. Larval Monitoring

The infestation index 1, which expresses the amount of pupae present in the fruits for the SAF, was 11.86 pupae/fruit. In the farm's orchard area, the infestation rate was 15.4 pupae/fruit. For the infestation index 2, which expresses the amount of pupae per kg of fruit, in the SAF there were 216.28 pupae / kg of fruit and in the FEA 284.48 pupae / kg.

The pupal viability for the SAF area was 25.84 %, a superior result when compared to the data for the FEA orchard area, which resulted in a pupal viability of 11.26 %.

After counting the larvae, pupae and flies that emerged during larval monitoring, specimens were identified. Of the 72 specimens, only eight were not identified as fruit flies. The remaining specimens, 64 in total, belonged to the genus *Anastrepha*. Of these 64, 24 were from the FEA and 40 from the SAF.

Based on the presented indices, despite the impossibility of deepening the statistical analysis for larval monitoring, it is possible to establish a perspective of population dynamics in the area. Both in the SAF and FEA areas, there are several hosts of fruit flies in the surroundings, which have different fruiting periods. Although these hosts may not be preferred hosts, they can maintain fruit fly populations throughout the year.

4. Discussion

The crown of the mountain guava together with the fruits has a green-yellow color and is in the 500 to 600 nm portion, that is, the greenish-yellow portion of the light spectrum in which insects are preferentially attracted, a typical light range of fruits mature, and mainly due to the green foliage of the plants [15–16]. Therefore, defining the size of the plant in the two areas evaluated is relevant to be able to associate the incidence of the insect with the possible effect of the plant's crown on the occurrence.

Among the reasons to capture only one *Ceratitis*, it is suggested that the Jackson trap and the trimedilure parapheromone would be more suitable for capturing males of *Ceratitis capitata*. Furthermore, the preferred hosts of *C. capitata* are, in most cases, exotic hosts according to [9–10].

In the FEA there was a trend of a much larger number of fruit flies collected during the fruiting of the mountain guava when compared to the SAF area, confirming the initial hypothesis. In the mountain guava orchard present in the FEA there was a greater presence of the insect possibly because there is a much larger number of plants, that is, it has a greater availability of hosts and also a greater concentration of volatiles.

As for the capture of more flies on the edges, it could possibly be related to the migration of flies from the surrounding areas, since other fruit hosts present in the surroundings of the studied areas were identified.

With the infestation index 1 it is possible to estimate the number of puparia / fruit and associate this value to the potential damage caused to each fruit, while the index 2 allows to have an estimate of damage for each kg of fruit.

The predominance of larvae of the *Anastrepha* genus in the fruit substrate is possibly due to the fact that it is considered ideal with regard to the development of these larvae [5].

With the data, it is possible to establish a perspective of the region's population dynamics. Both in the SAF and FEA areas, there are several hosts of fruit flies in the surroundings, which have different fruiting periods. Although these hosts may not be preferred hosts, they can maintain fruit fly populations throughout the year.

5. Conclusion

In the feijoa orchard present at the Experimental Agricultural Farm at UFSC - Campus Curitibanos there was greater abundance of fruit flies when compared to the area of the Agroforestry System (SAF).

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