Population fluctuation of *Anastrepha* spp. in Creole mango in four locations in Vinces, Ecuador

Fluctuación poblacional de *Anastrepha* spp. en mango criollo en cuatro localidades de Vinces, Ecuador

Flutuação populacional de *Anastrepha* spp. em manga crioula em quatro locais em Vinces, Equador

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Abstract

Within the genus *Anastrepha,* we find species that are key pests in fruit and vegetable crops and of quarantine importance for fruit importing countries. The knowledge of population fluctuation of these pests, in certain areas is a starting point for designing control strategies. The population fluctuation of fruit flies was evaluated in four localities of the Vinces canton, province of Los Ríos (La Americana, Santa Martha, Primavera and Pavana), using McPhail traps with hydrolyzed protein as bait. Three traps per site located on fruit fly host plants were checked weekly, in order to determine the fly.trap^{-1}.day^{-1} (MTD) index and its correlation with climatic variables. The results show that the population peak is concentrated in December, with a MTD of 5.94, with a temperature of 27.40 °C and 78% relative humidity. A moderate positive correlation was found between the number of captured insects and the temperature expressed in °C, with a correlative value r^2 = 0.61 and a negative correlation with relative humidity (r^2 = -0.64). The most abundant species was *Anastrepha fraterculus* (Wiedemann) with 3,111 specimens, of which 1,055 were found in La Americana, the location with the highest infestation.

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Resumen

Dentro del género *Anastrepha*, encontramos especies que son plagas clave en cultivos frutihortícolas y de importancia cuarentenaria para los países importadores de fruta. Conocer la fluctuación poblacional de estas especies plagas en determinadas zonas, es un punto de partida para diseñar estrategias de control. Se evaluó la fluctuación poblacional de las moscas de la fruta en cuatro localidades del cantón Vinces, provincia de Los Ríos (La Americana, Santa Martha, Primavera y Pavana), para ello se utilizaron trampas McPhail, con proteína hidrolizada como cebo. Tres trampas por sitio ubicadas en plantas hospederas de moscas de la fruta, revisadas con frecuencia semanal, a fin de determinar el índice de mosca.trampa^{-1}.día^{-1} (MTD) y su correlación con las variables climáticas. Los resultados muestran que el pico poblacional se concentra en diciembre con un MTD de 5,94 con temperatura de 27,40 ºC y 78% de humedad relativa, Se encontró una correlación positiva moderada entre el número de insectos capturados y la temperatura expresada ºC, con un valor correlativo de $r^2 = 0,61$ y en contraposición correlación negativa con la humedad relativa ($r^2 = -0,64$). La especie más abundante fue *Anastrepha fraterculus* (Wiedemann) con 3.111 especímenes de los cuales 1.055 se encontraron en La Americana, sitio con mayor infestación.

Palabras claves: Moscas de la fruta, *Mangifera indica*, Trampeo, trampas McPhail, proteína hidrolizada, dinámica poblacional.

Resumo

Dentro do gênero Anastrepha, existem espécies que são pragas chave nas culturas de frutas e vegetais e de importância quarentenária para os países importadores de frutas. Conhecer a flutuação populacional dessas espécies de pragas em certas áreas é um ponto de partida para o desenho de estratégias de controle. A flutuação populacional da mosca-das-frutas foi avaliada em quatro localidades do cantão de Vinces, província de Los Ríos (La Americana, Santa Martha, Primavera e Pavana), para isso foram utilizadas armadilhas McPhail, com proteína hidrolisada como isca. Três armadilhas por local em plantas hospedeiras de mosca-das-frutas, revisadas semanalmente, a fim de determinar o índice mosca^{-1}.armadilha^{-1}.dia^{-1} (MTD) e sua correlação com as variáveis climáticas. Os resultados mostram que o pico populacional se concentra em dezembro com MTD de 5,94 com temperatura de 27,40 ºC e 78% de umidade relativa do ar. Foi encontrada correlação positiva moderada entre o número de insetos capturados e a temperatura expressa em ºC, com um correlativo valor de $r^2 = 0,61$ e em contraste correlação negativa com a umidade relativa ($r^2 = -0,64$).. A espécie mais abundante foi *Anastrepha fraterculus* (Wiedemann) com 3,111 exemplares, dos quais 1,055 foram encontrados em La Americana, o local com maior infestação.

Palavras-chave: Fruit flies, *Mangifera indica*, Trapping, Armadilhas McPhail, proteína hidrolisada, Dinâmica populacional.

Introduction

Anastrepha Schiner (Diptera: Tephritidae) is a genus endemic to the Americas, distributed from the South of The United States to the North of Argentina, where important pest species are included (Hernandez-Ortiz *et al*., 2010). Within this genus, more than 200 species have been described such as *Anastrepha grandis* (Macquart), *A. fraterculus* (Wiedemann), *A. ludens* (Loew), *A. obliqua* (Macquart), *A. striata* (Schiner), *A. suspensa* (Loew) and *A. serpentina* (Wiedemann) pests of economic importance (Norrbom and Korytkowski, 2011).

The flies of the genus *Anastrepha* in Ecuador are associated with 56 host plant species, grouped into 23 botanical families. The Rutaceae, Myrtaceae and Sapotaceae families record six species of fruit flies each. *Psidium guajava* L. with seven fruit fly species, *Annona cherimola* Mill. and *Pouteria lúcuma* (Ruiz and Pay) with six species, are the main hosts in Ecuador (Tigrero, 2019).

The diversity of thermal floors in Ecuador has allowed the cultivation of several fruit species throughout the year, thus favoring the increase in *Anastrepha* spp. populations, generating an economic and social damage to the producer due to the deterioration in fruit quality and decrease in yield (Son *et al*., 2019).

In the Vinces area, flies of the genus *Anastrepha* are important pests in different fruit crops, being the ''sucking'' Creole mango one of their main hosts, especially in dry season (Gabriel-Ortega *et al*., 2017) where the infestation levels are estimated at 29.5% (Morales-Viteri, 2012).

The sucking mango is the most desired Creole variety in the domestic market, with a smooth yellow skin, yellow pulp with a pleasant flavor, average weight of 120 g, 10 to 17 cm in length by 5 to 7 cm in diameter, high fiber content and bulky size of the seed, these characteristics make it unqualified for the world market (Lozada, 2013).

Currently, there are some methods to eliminate these phytophagous diptera in postharvest such as exposing the fruit to hot air and/or hydrothermal treatments (Gómez-Simuta *et al*., 2017), controlled atmospheres, etc., in pre-harvest, the preventive method using traps and food attractants is still the most effective.

Navarro (2012) states that the correct layout of the trapping system for *Anastrepha*, is a precondition for making effective decisions in control programs aimed at suppressing pests and establishing free or low prevalence areas.

Therefore, the objective of this research was to evaluate the population fluctuation of *Anastrepha* spp., in the Creole mango variety in four localities of the Vinces canton, in order to learn more about the biology of these pest dipterans, and in turn to make future decisions about their management and control in this area.

Materials and methods

Study location

It was carried out in four localities. Primavera (1°40'45.9 S, 79°47'28.8 W), Pavana (1°43'17.5 S, 79°46'12.3 W), Santa Martha (1°35'42.7 S, 79°50'34.0 W) and La Americana (1°39'27.9 S, 79°49'36, 2 W) belonging to the Vinces canton, Los Ríos province, in individual trees of sucking Creole mango cultivar that form a diverse ecosystem, where cocoa, banana, rice and corn crops predominate. The research was developed from October 2018 to September 2019. Vinces has a tropical rainy climate, average temperature of 26.5 °C and an average annual precipitation of 1,400 mm with 800 hours of heliophany per year and 14 mamsl, belonging to the tropical dry forest, characterized by presenting two seasons. The dry season (summer) from July to December and the wet or rainy season (winter) from January to June.

Population fluctuation of species of the genus *Anastrepha*

To determine the population fluctuation of flies of the genus *Anastrepha,* a standardized sampling system was designed using

McPhail traps baited with the food attractant, hydrolyzed protein (12.5 mL of hydrolyzed protein, 7.5 g of Borax and 230 mL of water). A total of 250 mL of the solution was used and three traps were placed per location, always placed in "sucking" Creole mango plants. The monitoring frequency was weekly, the distance between traps was 100 m, placed between three and four meters high, where there was some shade. The captured flies were conditioned in jars with 70% alcohol and transferred to the entomophagous laboratory of the Facultad de Ciencias para el Desarrollo de Vinces for subsequent identification. In the identification a binocular stereoscope microscope (Nikon R, model YS-100) with micrometer and graduated scale and the taxonomic keys of Korytkowski (2001) and Tejada (2002) were used. The identified flies were left in the laboratory of the Facultad de Ciencias para el Desarrollo.

The number of adults captured weekly (Absolute abundance) per trap was transformed to the fly.trap^{-1}.day^{-1} (MTD) index, where the number of captured flies was divided by multiplying the number of traps and the exposure time of the trap in the field.

Fruits damaged by *Anastrepha* spp and percentage of adult emergence

The percentage of damaged fruits and percentage of adult emergence were determined with the formulas proposed by Núñez *et al*. (2004) and Schliserman and Ovruski (2004), where % of damage = Number of damaged fruits/ total fruits analyzed x 100 and the percentage of emergence = Number of emerged adults/ number of puparia x 100.

For the percentage of damaged fruits, semi-ripe mango fruit (*Mangifera indica* L.); was collected weekly from the tree in the four locations; guava (*Psidium guajava* L.); plum (*Spondias purpurea* L.); jobo (*Spondias mombin* L.) and cuaje (*Pouteria caimito* (Ruiz & Pav.) Radlk), the collected fruits were taken to the entomophagous laboratory of the Facultad de Ciencias para el Desarrollo, where they were washed with running water and then placed in breeding boxes for four days, on the fifth day the fruits were dissected to check whether or not there was the presence of *Anastrepha* larvae and thus determine the percentage of damaged fruits.

To establish the percentage of adult emergence, new fruits were collected from the aforementioned host plant species of *Anastrepha* spp, the collected fruits were placed in recovery boxes of 2 kg capacity and covered with a metal grid. Moistened fine sand was placed at the base of the box where the larvae could pupate. The pupae were collected by sifting the sand and placed in Petri dishes until the emergence of the adults, which were placed in 70% alcohol until identification.

Statistical analysis

The Pearson correlation coefficient was determined between the MTD and the climatic variables (temperature, humidity and precipitation) during the dry and wet seasons in the four sectors under study, in addition, a completely randomized analysis was performed with a significance level of 5% (α=0.05) comparing the *Anastrepha* species identified, using the statistical package: SAS (Statistical Analysis System) (SAS 1998). Meteorological data were obtained from the Babahoyo UTB meteorological station (1º 47'49 "S and 79º 32' 0 "W).

Results and discussion

***Anastrepha* abundance by month and time of year**

A total of 4,467 tephritid flies were captured, 2,647 females and 1,820 males, the peak population occurred in December 2018 with 2,138 specimens and an MTD index of 5.94 (table 1).

The high MTD index reached in December coincides with the transition from the dry season to the wet season and above all with the greater abundance of ripe plum and mango fruit, a species considered among the main hosts of *Anastrepha* and the most abundant in the Vinces area (table 2). While in July and August the MTD index was low due to the low availability of food, for those months there are ripe fruits of papaya (*Carica papaya* L.), a species poorly accepted by *Anastrepha* spp, guava (*Inga edulis* C. Mart) and mamey (*Pouteria sapota* (Jacquin), which are not very abundant hosts in the study area (table 2). Climatic factors (temperature and relative humidity) would have little influence on the population fluctuation of the pest, since there were only minor fluctuations in these environmental factors during the study.

Table 1. Abundance of *Anastrepha* spp. by time of year (dry and wet) in Vinces canton, Ecuador, between October 2018-September 2019.

Months	Seasons	Abundance of *Anastrepha* °C	Temperature	Relative humidity %	Precipitation (mm)
October	Dry	25	27.36	81	9.1
November	Dry	680	26.77	79	0
December	Dry	2138	27.4	78	30.4
January	Wet	970	27.13	85	278.9
February	Wet	626	26.79	88	449.8
March	Wet	15	26.84	87	420.8
April	Wet	2	26.9	86	250.4
May	Wet	2	26.87	90	69.3
June	Wet	5	26.8	91	1
July	Dry	1	26.68	89	0
August	Dry	1	26.68	87	0
September	Dry	2	26.77	85	0
Average		372.25	26.89	85.5	125.81
	Standard deviation		0.193	4.01	167.27

Source: Own elaboration

Fruit fly populations can vary from one year to another in correspondence with climatic conditions and host availability (Tucuch-Cauich *et al*., 2008). Similar results are reported by Ruiz-Graus(2020), for Olmos, Lambayeque region, Peru, where the highest MTD index (2.85) occurs in January with maximum temperatures of 34.2 °C and 65% relative humidity. In another study (Conde-Blanco *et al*., 2018) for the municipality of Caranivi, Bolivia, report that *Anastrepha* spp, reached its population peak in December with high temperatures and ripening of mangoes and oranges. On the other hand, Cañadas *et al*. (2014) for Santa Elena, Ecuador, indicate an explosion of the *A. fraterculus* population at the beginning of the rainy season and the second half of the year, where the dry weather prevails.

Table 2. Production season and fruits of the host fruit flies in Vinces, Ecuador.

Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mango (*Mangifera indica* L.)												
Pechiche (*Vitex gigantea* H.B. K)												
Jobo (*Spondias mombin* L.)												
Papaya (*Carica papaya* L.)												
Guava (*Inga edulis* C. Mart)												
Mamey (*Pouteria sapota* (Jacquin)												
Cauje (*Pouteria caimito)*												
Zapote (*Matisia cordata* Bonpl.)												
Plum (*Spondias purpurea* L.)												
Sweet orange (*Citrus sinensis* L.)												
Guava (*Psidium guajava* L.)												
Low fruit production						High fruit production						

Source: Own elaboration

MTD index by location – month

From November 2018 to February 2019 the MTD index for all localities was higher than 0.5 flies per trap, a value that according to the Colombian Agricultural Institute (ICA) is the reference index from which chemical control measures can be applied for *Anastrepha* spp. December presented the highest percentage (47.86 %) of flies trapped and the highest MTD in all localities. The highest MTD (8.27) was found in the Primavera locality; followed by the Pavana locality with 7.64; while in La Americana locality with 6.44 and Santa Martha with 1.40 (figure 1). The higher MTD recorded in December (dry season) is explained by the greater abundance of ripe fruits of Creole mango, the main host of *Anastrepha* in Vinces. The low MTD recorded between March and September 2019 would be due to the lower availability of host fruits, the host species (guava and cauje) with ripe fruits in those months are not very abundant in the study areas. Similar results were reported by Tucuch-Cauich *et al.* (2008) and Vanoye-Eligio *et al.* (2015) who found the highest MTD index in December, in the presence of ripe mango and sweet orange fruits. While Araujo *et al*. (2005) in Rio Grande do Norte, captured the largest number of flies in the last quarter of the year, with *C. capitata* being the only species associated at that time with mango fruits, while Ruiz-Graus (2020) obtained the highest capture indexes between May and July on the coast of Ceará.

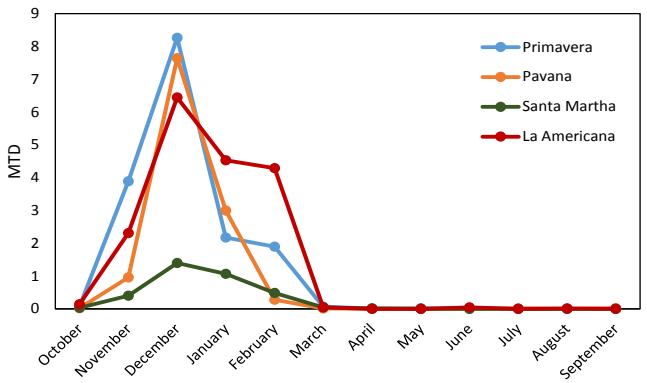

Figure 1. Capture index of Anastrepha spp. in four localities of Vinces, Ecuador.

When correlating the climatic variables (temperature, relative humidity and precipitation) with the MTD of the localities, no significant difference was found ($P \leq 0.05$). A moderate positive correlation was found between the number of captured insects and temperature expressed in ºC, ($r^2 = 0.61$) and a low positive correlation ($r^2 = 0.05$) between the number of captured insects and precipitation; on the other hand, between the number of insects and relative humidity, the variables were inversely related ($r^2 = -0.64$), finding significance ($P \leq 0.05$). As is known, the abundance of fruit flies is determined by abiotic (temperature, humidity, precipitation) and biotic factors (availability of host species, vegetation type and food availability) (Montoya-Alvarez *et al*, 2014). Results differ from those reported by Ramos-Peña *et al*. (2019) for the Abancay valley, Apurimac, Peru, who found a negative correlation between maximum temperature and the number of flies captured ($r^2 = -0.692$). Meanwhile (Calore *et al*., 2013) in Pindorama-SP, Brazil did not verify a correlation between the population of flies captured with precipitation, but did find significance with temperatures (minimum, average and maximum), indicating that the increase in the population of fruit flies was favored by high temperatures.

MTD index of *Anastrepha* species recorded by locality

The richness of the most abundant *Anastrepha* species in the four localities was similar, *Anastrepha fraterculus*, *Anastrepha obliqua*, *Anastrepha serpentina* and *Anastrepha striata* were identified. The most abundant species was *A. fraterculus* with 1,055 specimens in La Americana; 971 in Primavera; 856 in Pavana and 229 in Santa Martha. Statistical analysis reported highly significant differences (P=0.001) of *A. fraterculus* with an average of 778 per locality compared to the other species, which obtained averages of 208 for *A. oblicua*, 68 for *A. serpentina* and 64 for *A. striata*. The prevalence of *A. fraterculus* would be due to its high polyphagia; in Ecuador it is associated with 33 plant species (Tigrero, 2019). Similar results were obtained by Ramos-Peña *et al*. (2019) in Abancay, Apurímac, Peru and Gonzáles *et al*. (2011) in Coroico, Bolivia, in both investigations the predominant species was *A. fraterculus*.

The population fluctuation of the *Anastrepha* species by locality and month presented variations. In Primavera (figure 2) the highest MTD was recorded in December for the *A. fraterculus* and *A.*

oblicua species with values of 6.26 and 1.03. For Pavana (figure 2) the *A. fraterculus* and *A. serpentina* species reached the highest MTD index in December with values of 6.40; 0.88 and 0.18. In Santa Marta (figure 2) *A. fraterculus* and *A. serpentina* recorded the highest populations in December with a MTD of 1.16 and 0.04. Finally, in La Americana sector (figure 2) *A. fraterculus* and *A. serpentina* recorded the highest MTD in December with values of 4.42 and 0.43. The higher MTD reached in December would be related to the greater availability of hosts, which is confirmed by Vilatuña *et al*. (2010) who state that fruit fly populations are associated with host availability. The results of the present study are different from those reported by Emanoel da Costa Alves *et al*. (2020) who in Seridó in eastern Paraíba found the highest MTD in mango in July (0.51), August (4.31) and September (1.72). While Bermúdez-Vera *et al*. (2020) in Chone, Manabi, recorded a MTD of 0.20 flies per day of trap exposure.

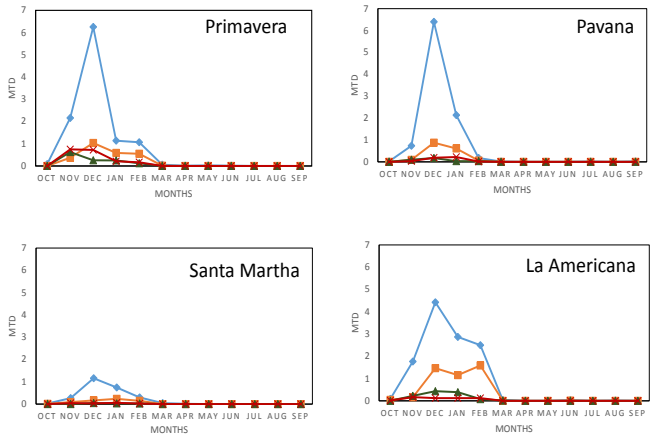

Figure 2. MTD index of *Anastrepha* species in the different localities.

Adult recovery and infestation level

A total of 511 flies grouped into four species were recovered. The most abundant species was *A. fraterculus* with 48.92%; followed by *A. obliqua* with 21.72%; *A. striata* with 20.55% and *A. leptozona* with 8.81%. The largest number of flies was recovered from mango (210), equivalent to 41.10%, *A. fraterculus* with 59.05% was the dominant species. A total of 822 mango fruits were collected, i.e., it had a targeted sampling during the present study, from 4 to 8 times more compared to other host species. From guava, 124 flies were rescued, which is equivalent to 24.27%, *A. fraterculus* with 65.32% was the dominant species; 12.72% were rescued from jobo; 13.11% from plum and 8.81% from cauje (table 3). The highest percentage of flies rescued from mango and guava would be due to the fact that mango is the most abundant fruit species and guava the most susceptible in the study area. Similar results are reported by Ruiz-Graus (2020) in Olmos, Lambayeque region, Peru, recovering 264 flies from Creole mango fruits in two successive seasons (2017-2018), 144 in the first and 120 in the second. In coincidence Pflücker and Marité (2015) in Chao and Viru, La Libertad, recovered the highest number of flies in guava and mango fruits.

Of the five plant species monitored, 1,465 fruits were collected, on average 21.09% showed damage by *Anastrepha.* The highest percentage of damaged fruits (34.63%) was found in guava, confirming the high susceptibility of this species to the attack of *Anastrepha*. The fruits of mango presented the lowest damage percentage (18.13%) (table 3), due to the greater abundance of fruits, the presence of an exocarp with numerous resinous ducts, and less susceptibility to *Anastrepha* attack (Aluja et al. 2014), fruit firmness (Díaz-Fleischer and Aluja, 2003). Different results were found by Obregón (2017) in the Socco and Amoca - Apurímac sectors, chirimoya presented 83.3% infestation by *A. distincta*, *A. schultzi* and *A. fraterculus* species, followed by guava with 73.8%, being *A. schultzi*, *A. fraterculus* and *A. distincta* the most frequent species. While Miranda-Salcedo (2018) in Michoacán in marginal orchards of creole mango found 39% of damaged fruits, being the identified species *A. ludens* (85%), *A. striata* (12%) and *A. obliqua* (3%).

Table 3. Hosts and recovery of *Anastrepha* adults in Vinces, Ecuador.

Plant species	*Anastrepha* species	Nº of recovered adults	Nº of collected fruits	Percentage of damage/fruit	Percentage of emergence (adult/fruit)
Mango (*Mangifera indica*)	*A. fraterculus*	124	822	18.13	25.55
	A. striata	52			
	A. oblicua	34			
Plum (*Spondias purpurea*)	*A. fraterculus*	0	243	20.16	27.57
	A. striata	0			
	A. oblicua	67			
Jobo (*Spondias mombin*)	*A. fraterculus*	45	93	21.51	69.89
	A. striata	20			
	A. oblicua	0			
Guava (*Psidium guajava*)	*A. fraterculus*	81	231	34.63	53.68
	A. striata	33			
	A. oblicua	10			
Cauje (*Pouteria caimito*)	*A. leptozona*	45	76	14.47	59.21

Source: Author's elaboration

Adults of *Anastrepha* emerged from 100% of the evaluated plant species. The highest percentage, 87.5%, was found in April for jobo, in March for cauje with 81.57%, and in mango 45% in December (figure 3). The high indexes of adult emergence in most of the plant species sampled are explained by the low abundance of these species in the study area, the absence of management practices and the polyphagia of the *Anastrepha* species identified.

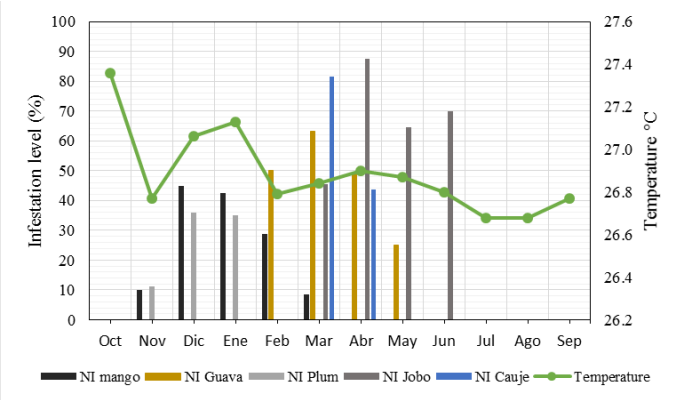

Figure 3. Level of infestation by fruit species and time of year.

Conclusions

The population fluctuation of fruit flies is associated with the fruiting period of the host plant species. The maximum populations were recorded in the transition from the dry season to the wet season (December-January), coinciding with the greatest abundance of ripe Creole mango fruits, temperatures higher than 27.40°C and lower relative humidity (78%).

Of the *Anastrepha* species identified (*A. fraterculus*, *A. serpentina, A. striata* and *A. obliqua*), *A. fraterculus* predominates in all four locations. La Americana recorded the highest incidence of the pest and percentage of damaged fruits.

Four species of *Anastrepha* (*A. fraterculus*, *A. obliqua, A.striata* and *A. leptozona)* were also recovered from fruits, being *A. fraterculus* with 48.92% the most recovered species, from mango, the highest percentage of tephritid flies (41.10%) was rescued in December, where *A. fraterculus* with 59.05% is the dominant species.

The present research provides basic information useful for designing management strategies for *Anastrepha* spp. in the localities under study and in other localities with similar agroclimatic conditions.

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