Full Length Research Paper

Diversity and infestation indices of fruit flies (Diptera: Tephritidae) in guava (*Psidium guajava* L.)

Alba Albertina Sarmento Maciel[1], Raimunda Nonata Santos de Lemos[1]*, Almerinda Amélia Rodrigues Araújo[1], Keneson Klay Gonçalves Machado[1], Ester Azevedo da Silva[1], José Ribamar Gusmão Araújo[1] and Mário Luiz Ribeiro Mesquita[2]

[1]Graduate Program in Agroecology, Maranhão State University, 65055-098, C.P. 09. São Luís, Maranhão, Brazil.
[2]Bacabal Campus, Maranhão State University, Maranhão, Brazil.

The fruit flies are considered major pests in the world fruit production due to the direct damage they cause to fruits and the ability to adapt to areas where they are introduced. The objective of this research was to study the fruit fly diversity, the infestation indices in fruits and to characterize the tephritids community in a guava (*Psidium guaja*va L.) cultivar "Paluma", in a commercial orchard located in São Luís, state of Maranhão, northeastern Brazil. In the survey, fly hunting bottles containing hydrolyzed protein in a ratio of 500 ml/10 L of water were used. To assess the infestation indices, fruits were collected, individualized in plastic containers with sterile sand, and kept in a climate-controlled chamber. 2,901 specimens of fruit flies were collected. From these, 2,328 were collected in traps and 573 in fruit samples. The species found belong to the genus *Anastrepha,* including *Anastrepha striata, Anastrepha obliqua, Anastrepha fraterculus, Anastrepha sororcula, Anastrepha distincta*, *Anastrepha zenildae* and *Anastrepha pickeli*. Considering the total tephritids collected in fruits and traps, a low diversity (H' = 0.2689 and 0.4147, respectively) was found. *A. striata* predominated among the collected species. The largest number of insect pests captured occurred in May 2008, a period of increased guava fruit availability in the orchard. The infestation indices were 231.02 pupae/kg and 26.42 pupae/fruit.

Key words: Tephritids, Myrtaceae, population dynamics, ecology.

INTRODUCTION

Fruit production in Brazil has grown significantly and the country holds a prominent position in the international market by increasing the position of fruit growing in the national economy. Brazil is the third largest fruit producer

in the world and is a leading producer of tropical fruits (FAOSTAT, 2013).

The marketing of fresh fruit in the world is severely limited by the occurrence of fruit fly (Diptera: Tephritidae), which is considered as one of the main pests of the world fruit production, due to the direct damage they cause and the ability to adapt in other areas, where introduced (Godoy et al., 2011). Yield losses due to fruit damages caused by fruit flies is associated with high control costs, and affect international trade relations due to phytosanitary restrictions that are imposed (Godoy et al., 2011). The tephritids economic importance is due to the yield losses they cause in world fruit production, since they feed on fruits from several species. Moreover, they are quarantine pests (Araujo et al., 2013).

Guava (*Psidium guajava* L., Myrtaceae) is one of the most attacked fruits in Brazil by the fruit fly species *Anastrepha* spp. and *Ceratitis capitata* (Wied).

The population of fruit flies fluctuates due to a succession of primary or alternate hosts, the environment complexity and abiotic factors (Montes et al., 2011). The average temperature (°C) inversely influences the fruit fly occurrence, for example, lower temperatures favor an increase in the Tephritidae population (Araujo et al., 2008). With a population monitoring study, it is possible to follow the pest fluctuation in a specific area, to detect exotic or quarantine species, allowing for a more comprehensive characterization of the insect pest population in qualitative and quantitative terms.

Knowledge of fruit fly species of economic importance in a particular area, can only be obtained based on intensive surveys, made directly from host fruit, which enables detection of larvae present in the fruit, the degree of infestation in an orchard and the direct damage caused by the flies. Therefore, there is a need to determine the guava fruit infestation indices and to identify the fruit fly species that occur in the state of Maranhão, northeastern Brazil, in order develop low environmental impact strategies to control this insect. Thus, the aim of this work was to study diversity, the fruit infestation rates and to characterize the tephritid community in a commercial orchard of guava by faunal analysis.

MATERIALS AND METHODS

The research was conducted in a guava cultivar "Paluma", commercial orchard located in Vila Maracanã district, in the São Luís island (02°31'47'' S and 44°18'10'' W), state of Maranhão, northeastern Brazil.

The orchard was eight years old and was composed of 1,200 plants. The guava plant spacing was 6 × 5 m. The soil is from Itapecuru formation, classified as Latossol. The orchard was sprinkler irrigated with 6 mm water per plant every three days during the dry season.

Fourteen MacPhail model traps with attractive food (5% corn hydrolyzed protein, stabilized with borax), were installed under the tree canopies with 1.5 m height from the ground. Samples were collected every two weeks from February 2008 to January 2009. The captured insects were water sieved, separated by sex, counted and stored in bottles containing 70% alcohol solution for taxonomic identification, which was done based on the terminalia of female specimens, observing the aculeus. They were identified using a key from Zucchi (2000).

Mature fruits were collected at random on the top and from the ground under the trees to check the infestation rates. The fruits were weighed on a precision electronic scale in laboratory conditions and individually packaged in plastic containers with a thin layer of sterile sand (1.5 to 2.0 cm in height) on the bottom, to allow larvae to become pupae. These containers were covered and kept in a climate chamber of BOD type with temperature 25 ± 2°C and relative humidity 70 ± 10%, with photoperiod of 12 h and inspected every 48 h.

After 10 to 15 days, the substrate was sieved (1.5 mm mesh size) and the obtained pupae were counted and wrapped in transparent plastic containers with 6.5 cm in height and 4.5 cm in diameter, provided with a plastic cover pressure, for adult emergence observation. Thereafter, the adults were preserved in 70% alcohol solution for further identification.

Two parameters were used to obtain the infestation indices. The first was the number of pupae per fruit (pupae/fruit) and the second, the number of pupae per kg of fresh fruit (pupae/kg) (Araujo and Zucchi, 2003). Each infestation index refers to the average value obtained for the samples of infested host species. The maximum and minimum values indicate the indices variation according to the place of collection and the number of samples examined.

The fruit fly species faunal analyses was done by means of the software ANAFAU (Moraes et al., 2003). The tephritid community was characterized by the indices of frequency, constancy, richness, dominance and predominant species. The indices of evenness and the Shannon-Weaner diversity were also computed. The definition of extreme classes (super) was based on the class hierarchical classification (Silveira Neto et al., 1976).

RESULTS AND DISCUSSION

Considering all collections, a total of 2,901 specimens of fruit flies were obtained. All species belonged to the genus *Anastrepha,* including *Anastrepha striata* (Schiner, 1978), *Anastrepha obliqua* (Macquart, 1835), *Anastrepha fraterculus* (Wiedmann, 1980), *Anastrepha sororcula* (Zucchi, 1979), *Anastrepha distincta* (Greene, 1934), *Anastrepha zenildae* (Zucchi, 1979) and *Anastrepha pickeli* (Lima, 1934). From this total, 2,328 specimens were collected in the traps and 573 were obtained from the fruits. The mean pupal viability was 42.85% for the entire study period (Tables 1 and 2).

A total of 273 female flies were identified in the guava fruits. *A. striata* was the major species reaching 94.5% of the total (Table 3). The presence of *A. striata* in this orchard suggests that there was a spread of this insect pest, since this species is more common in the north region of the country (Zucchi et al., 2011). *A. striata* was also the major species found in the traps, reaching 90.8%

Table 1. *Anastrepha* spp. (Diptera: Tephritidae) collected in a commercial orchard of guava cv. Paluma in São Luis, state of Maranhão, northeastern Brazil.

Species	Number of adult tephritids		
	Collected in traps	Collected in fruits	Total
Anastrepha striata	1,671	550	2,221
Anastrepha obliqua	526	11	537
Anastrepha fraterculus	78	04	82
Anastrepha sororcula	22	06	28
Anastrepha distincta	17	00	17
Anastrepha zenildae	12	02	14
Anastrepha pickeli	02	00	02
Total	2,328	573	2,901

Table 2. Number of pupae and adults of *Anastrepha* spp. (Diptera: Tephritidae) obtained in fruits of guava cv. Paluma in São Luis, state of Maranhão, northeastern Brazil.

Period	Number of pupae	Number of adults	Pupae viability (%)
February/08	9	5	55.55
March/08	30	16	53.33
April/08	132	49	37.12
May/08	250	97	38.80
June/08	73	29	39.72
July/08	107	37	34.57
August/08	370	169	45.67
September/08	151	60	39.73
October/08	126	61	48.41
November/08	14	08	57.14
December/08	47	26	55.31
January/09	28	16	57.14
Total	1,337	573	42.85

Table 3. Number of females of *Anastrepha* spp. (Diptera: Tephritidae) collected in a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Anastrepha spp.	Collected in fruits		Collected in traps	
	No.	%	No.	%
A. striata	258	94.5	1,145	90.8
A. obliqua	09	3.3	59	4.7
A. sororcula	04	1.5	18	1.4
A. fraterculus	01	0.4	34	2.7
A. distincta	-	-	03	0.2
A. zenildae	01	0.4	01	0.1
A. pickeli	-	-	01	0.1
Total	273	100	1,261	100

of the total (Table 3). Some fruit fly species associated with their hosts have been recorded in the state of Maranhao including *A. obliqua* in starfruit (*Averrhoa carambola* L.), *A. striata* in both guava and hog plum

Table 4. Faunal analysis of the *Anastrepha* spp. (Diptera: Tephritidae) collected in fruits in a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Species	Number of Individuals	Number of Collections	Domin[1]	Abund[2]	Freq[3]	Const[4]
A. striata	258	12	D	va	VF	W
A. obliqua	09	03	ND	va	F	Y
A. sororcula	04	02	ND	va	F	Z
A. fraterculus	01	01	ND	va	F	Z
A. zenildae	01	01	ND	va	F	Z

Shannon-Weaner diversity index = H' = 0.2689; Variance H = V(H)= 0.0030; confidence interval (P=0.005) H = [0.262293; 0.275450];
[1]Dominance: SD = super dominant; D = dominant; ND = non dominant; [2]Abundance: va = very abundant; a = abundant; c = common; d = disperse; [3]Frequency: VF = very frequent; F = frequent; [4]Constancy: W = constant; Y = accessory; Z = accidental.

Table 5. Faunal analysis of A*nastrepha* spp. (Diptera: Tephritidae) collected in traps in a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Species	Number of Individuals	Number of collections	Domin[1]	Abund[2]	Freq[3]	Const[4]
A. striata	1.145	12	SD	AS	VF	W
A. obliqua	59	04	D	VA	F	Y
A. sororcula	18	03	ND	C	F	Y
A. fraterculus	34	04	ND	C	F	Y
A. distincta	03	01	ND	C	F	Z
A. zenildae	01	01	ND	C	F	Z
A. pickeli	01	01	ND	C	F	Z

Shannon-Weaner Diversity Index = H = 0.4147; Variance H = V(H) = 0.0008; Confidence interval (P=0.005) H = [0.413043; 0.416298];
[1]Dominance: SD = super dominant; D = dominant; ND = non-dominant; [2]Abundance: SA = super abundant; VA = very abundant; A = abundant; C = common D = disperse; [3]Frequency: VF = Very frequent; F = frequent; [4]Constancy: W = constant; Y = accessory; Z = accidental.

(*Spondias purpurea* L.) in the municipality of Caxias and *A. zenildae* in guava (Oliveira et al., 2000) in the municipality of Santa Inês. Lemos et al. (2002), also found the predominance of *A. striata* in guava in the municipality of Itapecuru Mirim.

Azevedo et al. (2010) and Santos et al. (2011), studying the main hosts of *Anastrepha* spp. found that *A. fraterculus, A. sororcula*, *A. striata* and *A. zenildae* focus on Myrtaceae, which has wide geographic distribution across the continent. This finding was possible due to to the fruit fly surveys carried out in the Cariri region, state of Ceará and the extreme south of the state of Bahia, respectively, both in the northeastern Brazil.

Azevedo et al. (2010), found four *Anastrepha* spp. including *A. zenildae*, *A. sororcula*, *A. fraterculus*, *A. obliqua* and *Ceratitis capitata* associated with guava in the Cariri region, state of Ceará. Duarte et al. (2013) noted greater diversity of *Anastrepha* spp. in guava fruits in the state of São Paulo, southeast Brazil. Lima et al. (2012) observed that *A. striata* and *A. obliqua* predominated among the four species observed in mango orchards (*Mangifera indica* L.), in Boa Vista, state of Roraima, northern Brazil.

Among the species collected in traps, there was the species *A. pickeli*, not yet recorded in the state of Maranhao. Araujo et al. (2009) recorded *A. pickeli* for the first time in the municipality of Mossoró, state of Rio Grande do Norte. Azevedo et al. (2010) also found *A. pickeli* in a study carried out in Cariri, state of Ceará, both states are located in northeastern Brazil.

Considering the total number of tephritids collected in fruits and traps, a low diversity (H' = 0.2689 and 0.4147, respectively) was found. The faunal analysis indicated that *A. striata* predominated among the species collected in fruits (Table 4) and traps (Table 5). Marsaro Junior et al. (2013) noted that *A. striata, A. sororcula A. obliqua* and *A. fraterculus* were the most frequent and predominant species found in a guava orchard in Boa Vista, state of Roraima, northern Brazil. These fruit fly species are reported as major insect pests of guava.

A. obliqua stood out as the dominant, very abundant and very common species whereas the others were only considered as frequent. Similarly, Oliveira et al. (2009) found that *A. obliqua* reached a very frequent rate in mango orchard in the coast of the state of Ceará. However, Zilli and Garcia (2010) and Alberti et al. (2012)
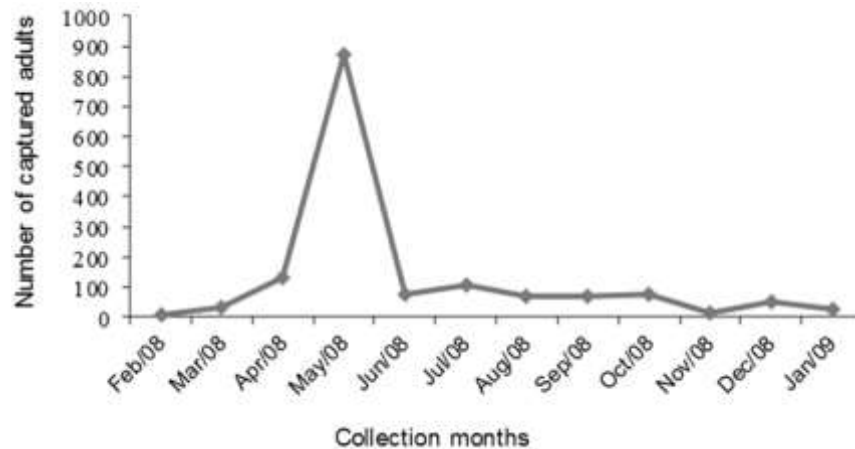
Figure 1. *Anastrepha* spp. (Diptera: Tephritidae) population fluctuation captured in traps in a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Table 6. *Anastrepha* spp. (Diptera: Tephritidae) indices from a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Period	Number of fruit samples	Average fruit mass (kg)	Average fruit weight (g)	Number of pupae	Pupae/kg	Pupae/fruit
February/08	12	2.0	0.164	09	4.5	0.75
March/08	24	3.9	0.160	30	7.7	1.25
April/08	20	2.9	0.144	132	45.5	6.60
May/08	42	6.1	0.144	250	40.9	5.95
June/08	28	3.7	0.133	73	19.7	2.60
July/08	28	4.3	0.153	107	24.8	3.82
August/08	14	1.6	0.113	370	231.2	26.42
September/08	16	1.2	0.072	151	125.8	9.43
October/08	30	2.8	0.093	126	45.0	42.0
November/08	30	4.2	0.140	14	3.3	0.46
December/08	40	4.9	0.123	47	9.5	1.17
January/09	20	3.1	0.155	28	9.0	1.40

noted *A. obliqua* as uncommon in orange orchard (*Citrus sinensis* Pers.) in Chapecó and Iraceminha municipalities both located in the state of Santa Catarina, southern Brazil.

With regards to the *Anastrepha* spp. population fluctuation, there was a higher incidence of flies captured in May 2008, when fruits were found in abundance in the orchard (Figure 1). These results are similar to those reported by Araujo et al. (2008), Alberti et al. (2012), Santos et al. (2013) and Duarte at al. (2013) who explained that a high incidence of fruit flies can be related to the greater presence of fruit in the orchard.

A total of 304 guava fruit samples were obtained from February 2008 to January 2009. The average fruit weight varied from 0.072 to 0.165 kg. The average number of pupae obtained from these fruits varied from 9 to 370 individuals (Table 6). Infestation rates for guava commercial orchard in São Luis, state of Maranhão, northeastern Brazil, was higher in August and September 2008, reaching 231.2 pupae/kg and 26.42 pupae/fruit; and 125.8 pupae/kg and 9.43 pupae/fruit, respectively.

Several factors may influence the fruit fly infestation indices in orchards. Azevedo et al. (2010) studying commercial orchards in the Cariri region noted that these tephritids population fluctuation is directly related to the availability of host fruits and the amount of rainfall in the

region. In commercial orchards dominated by a single host, the largest population peak occurs at the time of greater availability of ripe fruits (Azevedo et al., 2012).

Conclusions

The *Anastrepha* spp. recorded in association with guava in the commercial orchard were *A. striata*, *A. obliqua*, *A. fraterculus*, *A. sororcula*, *A. distincta*, *A. pickeli* and *A. zenildae*. *A. pickeli* was recorded for the first time in the state of Maranhao. *A. striata* was the most frequent, dominant and constant species in the guava commercial orchard. The largest number of captured insects occurred in May 2008, a period of increased availability of fruits in the orchard. The highest *Anastrepha* spp. infestation index in guava fruits was recorded in August 2008.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

ACKNOWLEDGMENTS

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