Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Ecotone effect on the fruit fly assemblages (Diptera: Tephritidae) in natural and anthropized environments

Efeito do ecótono nas comunidades de moscas-das-frutas (Diptera: Tephritidae) em ambientes naturais e antropizados

M. A. Uchoa[a]*, V. L. Pereira-Balbino[b] and O. Faccenda[c]

[a]Universidade Federal da Grande Dourados – UFGD, Faculdade de Ciências Biológicas e Ambientais – FCBA, Laboratório de Taxonomia e Sistemática de Tephritidae – LabTaxon, Dourados, MS, Brasil

[b]Universidade Federal de Mato Grosso do Sul – UFMS, Pró-Reitoria de Pesquisa e Pós-graduação – PROPP, Diretoria de Pós-graduação – DIPOS, Secretaria de Pós-graduação – SEPOS, Campo Grande, MS, Brasil

[c]Universidade Estadual de Mato Grosso do Sul – UEMS, Curso de Ciência da Computação, Dourados, MS, Brasil

Abstract

Various species of fruit flies are important pests of fruit cultures and in some crop of vegetables worldwide. Studies of their population patterns, ecological processes and mechanisms that influence their sampling and distribution in the ecosystems, provides important information to support researches on species diversity and ecologically based pest control programs. The aims of this paper were to analyze the patterns of fruit fly species: diversity, abundance and composition in the margin and inside of a fragment of native forest (35 ha); on the margin and in the inside a commercial orchard (2.5 ha). This research was carried out in transects in a fragment of semideciduous forest and in a commercial orchard in the region of Dourados, Mato Grosso do Sul, Brazil. A total of 1,918 adult fruit flies: 1,350 *Ceratitis capitata* (Wiedemann) (♂♂+♀♀) and 568 of the genus *Anastrepha* Schiner (275♂♂ + 293♀♀) from six infrageneric groups and 12 different species were captured. *C. capitata* (80%), and *Anastrepha sororcula* Zucchi were the most abundant species, being this last one representing 50.68% of individuals in the genus *Anastrepha*. There are significant differences in species diversity of fruit flies caught in the traps installed in the edge and inside of both environments: traps installed in the forest edge had higher diversity index (H' = 2.13) in compare to the inside of forest (H' = 1.67), with the same pattern repeated in the orchard: edge (H' = 0.55) and inside (H' = 0.41). The results in this paper corroborate with the prediction that in ecotonal areas between environments there are higher diversity in compare with the inside of each of the confronting ecosystems. The technique proposed here saves time, effort and resources in rapid inventories for sampling fruit fly species richness in natural forests and large fruit tree orchards.

Keywords: *Anastrepha barnesi*, diversity sampling, biodiversity, edge effect, Insecta, quick inventories.

Resumo

Várias espécies de moscas-das-frutas são importante pragas da fruticultura e de algumas hortaliças mundialmente cultivadas. Estudos sobre seus padrões populacionais, processos ecológicos e mecanismos que influenciam na amostragem e distribuição das espécies nos ecossistemas fornecem informações importantes para apoiar pesquisas sobre diversidade de espécies e programas ecologicamente embasados de controle de pragas. Os objetivos deste trabalho foram analisar os padrões de diversidade e comparar a abundância e a composição de espécies de moscas-das-frutas na margem e no interior de um fragmento de floresta nativa (35 ha); na margem e no interior de um pomar comercial (2,5 ha). Esta pesquisa foi realizada em transectos de uma floresta semidecidual e em um pomar comercial na região de Dourados, Mato Grosso do Sul, Brasil. Foram capturados 1.918 adultos de moscas-da-frutas: 1.350 de *Ceratitis capitata* (Wiedemann) (♂♂+♀♀) e 568 do gênero *Anastrepha* Schiner (275♂♂ + 293♀♀), pertencentes a seis grupos infragenéricos e 12 diferentes espécies. *C. capitata* (80%) e *Anastrepha sororcula* Zucchi foram as espécies mais abundantes, tendo esta última representado 50,68% dos indivíduos do gênero *Anastrepha*. Houve diferença significativa na diversidade de espécies capturadas entre a borda e o interior dos ambientes: as armadilhas instaladas na margem da floresta apresentaram maiores índice de diversidade (H' = 2,13), em comparação com aquelas do seu interior (H' = 1,67), sendo o mesmo padrão repetido no pomar: borda (H' = 0,55) e interior (H' = 0,41). Os resultados deste trabalho corroboram com a premissa de que no ecótono (efeito de borda), há uma maior diversidade de espécie que no interior de cada um dos ecossistemas confrontantes. A técnica aqui proposta economiza tempo, esforço e recursos em inventários rápidos para amostragem da riqueza de espécies de moscas-das-frutas em florestas naturais e grandes pomares de árvores frutíferas.

Palavras-chave: *Anastrepha barnesi*, amostragem de diversidade, biodiversidade, efeito de borda, Insecta, inventários rápidos.

*e-mail: uchoa.fernandes@ufgd.edu.br
Received: March 28, 2023 – Accepted: September 9, 2023

This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Various species of fruit flies (Diptera, Tephritidae) are important pests of fruits crops and vegetables worldwide. They cause significant losses to production and limit the free transportation of agricultural commodities due to quarantine restrictions imposed by importing countries, because some fruit flies are of quarantine importance. The economically import Tephritidae pest of fruit and vegetables in Brazil, are: *Ceratitis capitata* (Wiedemann), *Bactrocera carambolae* Drew & Hancock (both exotic), and eight species of *Anastrepha* (*A. fraterculus* (Wiedemann), *A. grandis* (Macquart), *A. obliqua* (Macquart), *A. sororcula* Zucchi, *A. striata* Schiner, *A. zenildae* Zucchi (Zucchi, 2023), *A. pseudoparallela* (Loew) and *A. serpentina* (Wiedemann) (Uchoa, 2012). *Ceratitis capitata* is native from Africa and was detected 1901 in São Paulo-SP, while *Bactrocera carambolae* Drew & Hancock, is native from Asia (Indonesia, Malaysia and Thailand), and first detected at Oiapoque, Amapá state in 1996, coming from Suriname (Uchoa, 2012).

Brazil is the country with the highest diversity of fruit fly species in the Neotropical Region, where are reported about 70 genus and around 820 species of Tephritidae (Norrbom, 2010). Currently there are 328 species of *Anastrepha* described worldwide (Norrbom et al., 2018; Zucchi, 2023), being from that total, 128 reported in Brazil (Zucchi and Moraes, 2023). However, distribution of fruit flies by regions and their host plants are poorly studied, being that for 68 *Anastrepha* species (53.12%) has no yet host fruit recorded (Zucchi and Moraes, 2023).

In Mato Grosso do Sul state (MS), Mid-West Brazil, the process of deforestation in natural environments, such as phytophysiognomies of Atlantic Forest, Cerrado, Pantanal, and Chaco, led to the formation of isolated fragments, becoming one of the main threats to the diversity and stability of animal and plant populations (Carvalho et al., 2009; Ribeiro et al., 2009; Uchoa and Nicácio, 2010; Coelho and Uchoa 2023). Despite of Mato Grosso do Sul has a huge part of their natural forests removed to make up agrossilvipastoral (Agriculture, Pasture and Artificial Forest of *Eucalyptus* spp.) systems, 33 species of fruit fly (32 of *Anastrepha* and *C. capitata*) are reported in orchards and natural environments (Uchoa et al., 2023) by now. However, the real diversity of fruit fly in MS is certainly higher. For all five geographic regions of Brazil, only 128 *Anastrepha* species is reported (Zucchi and Moraes, 2023), and more sampling effort is required, even if by quick inventories techniques, which need to be discovered.

The studies of fruit fly species population patterns, and the techniques that influence their sampling in natural e anthropized environments, provides important information to support biological control programs, as well as other attitudes that allow the human coexistence with pest species in agroecosystems (Uchoa et al., 2021; Monteiro et al., 2021), taking into account the biota (living being) and biotope (physical environments) conservation.

An ecotone is defined as a transition borderline between two adjacent ecosystems. It has common features to both types of confronting environments, and generally the species of both environments overlap in the edge of these two ecosystems. These intersections (ecotones) are usually considered richer in wildlife than each of the adjacent environments (Naiman et al., 1989; Kark and van Rensburg, 2006; Kark, 2017). According to Ewers and Didham (2007), the edges or ecotones between two different environments have profound effects on the dynamics of species and communities of anthropized landscapes. Therefore, the hypothesis of this study is that in quick inventories about fruit fly species, the traps installed in the ecotones (edges) of forests or orchards, will capture higher diversity that traps installed in the inside (center) of those environments. In this context, the aim of this paper is to compare the patterns of fruit fly species (abundance and species richness), captured with food bait in McPhail traps installed on the ecotone (borderline), and inside (center) of two ecosystems: a fragment of semi-deciduous forest, and in a commercial orchard with several species of fruit trees.

2. Material and Methods

2.1. Studied areas

The survey was carried out in two different environments, from June 2005 to June 2007. The first environment is a native forest fragment with 35 ha of total area (22º 12' 44.36" S, 54º 55'13.83" W), 430 m of altitude, known as *Reserva Florestal Fazenda Coqueiro*, located two kilometers from the Highway MS-162, and nine km from Dourados downtown, state of Mato Grosso do Sul (MS), Brazil.

The forest have phytophysiognomy of tropical semi-deciduous forest (Atlantic Forest domain), composed mainly by plants from the families: Annonaceae, Apocynaceae, Araliaceae, Aquifoliaceae, Boraginaceae, Burseraceae, Caricaceae, Cecropiaceae, Clusiaceae, Euphorbiaceae, Flacourtiaceae, Lauraceae, Fabaceae, Papilionaceae, Mimosaceae, Meliaceae, Melastomataceae, Myrsinaceae, Myrtaceae, Moraceae, Rubiaceae, Rutaceae, Sapindaceae and Sterculiaceae. Herein, eight McPhail traps were distributed in two transects (four traps in each), with weekly collections for two consecutive years (106 weeks). Traps were placed in an area of approximately 2.5 ha (Figure 1A). About 250m from the forest there are houses with orchards of fruit tree species (*e.g.* guava, *Psidium guajava* L. mango, *Mangifera indica* L. hog plum, *Spondias purpurea* L., barbados cherry, *Malpighia emarginata* DC., orange, *Citrus sinensis* Osbeck and peach, *Prunus persica* (L.).

The second site is located at an approximate distance of 28 km from the native forest. The area of this diversified orchard is of about 2.5 ha, located in the *Parque de Exposições João Humberto de Carvalho* (BR 163, Km 10; 22º 13' 51.81" S, 54º 43' 53.03" W, and 411 m of altitude), in the region of downtown Dourados-MS (Figure 1B). There is no more native vegetation on the nearby.

In this orchard are cultivated 11 fruit trees, planted in rows arranged as follows: peach, *Prunus persica* L. (Rosaceae) (five rows with about 50 plants [n = 250], and each row arranged 2 m between each tree); palmetto, *Bactris gasipaes* K. (Arecaceae) (five rows with about nine plants [n = 45], placed at 5 m from each other; persimmon, *Diospyrus kaki* L. (Ebenaceae) (a row with 10 plants

[n = 10], placed 10 m from each other); fig, *Ficus carica* L. (Moraceae) (five rows with 50 plants [n = 250], willing to 2 m apart); guava, *Psidium guajava* L. (Myrtaceae) (eight rows with about 10 plants [n = 80], placed 10 m from each other); soursop, *Annona muricata* L. (Annonaceae) (two rows with about 10 plants [n = 20], placed 10 m apart); mango, *Mangifera indica* L. (a row with about 10 plants [n = 10], placed 10 m from each other) (Anacardiaceae); grape, *Vitis vinifera* L. (Vitaceae) (12 rows with about 25 [n = 300], the plants placed 2.30 m apart); atemoya (*Annona squamosa* L. x *Annona cherimoya* Mill) (Annonaceae) (a row with about 10 plants [n = 10], placed 10 m between each other); coconut palm, *Cocos nucifera* L. (Arecaceae) (about seven rows of seven plants [n = 49], willing to 7 m from each other) and banana, *Musa* spp. (Musaceae) (five rows with about nine plants [n = 45], placed 5 m from one to another). This area is surrounded to the east with soybeans, *Glycine max* (L.), cotton, *Gossypium hirsutum* L., maize, *Zea mays* L. sorghum, *Sorghum bicolor* L. sunflower, *Helianthus annus L*, and backyard guava (*P. guajava*) orchards.

The climate of Dourados region is tropical continental, with two well defined seasons: tropical humid in summer (December to March) and tropical dry during the winter (June to September). The average temperature in summer is 26.4 °C and 19.8 °C in winter. Annual average temperature in the period was 23.6 °C (EMBRAPA, 2008).

2.2. Trap samplings

The collections were made with McPhail traps containing the food bait hydrolyzed corn protein 5% (stabilized with borax), employing about 300 mL per trap. In the forest eight traps were installed in two transects: one at the ecotone (four traps) and the other four traps in the forest center. The traps were placed about 40 m apart from each other (see Flores et al., 2017; Malavasi and Souza, 2023).

In the commercial orchard also, eight traps were installed in two transects, being four traps in the edge and four on the inside (center). All traps, like in the forest, were also placed about 40 m apart from each other. These were installed in the following fruit trees: peach, *P. persica*, fig, *F. carica* guava, *P. guajava* and mango, *M. indica*. This procedure was repeated weekly over two years, totaling up 106 sampled weeks. Sample unit were represented by each McPhail trap (n = 4 traps by each sub environment: edge or inside).

The traps were suspended approximately 1.70 m from the ground level, attached to the branches of the trees (Uchoa et al., 2003). The collections of the fruit flies in both environments were done always on the same day of the week. In each inspection the traps were washed, and new attractive solution added. All the insects trapped were stored in labeled bottles containing 90% ethanol, taken to the laboratory, where the species of fruit flies were identified. The voucher specimens of Tephritidae were deposited at the *Coleção Entomológica*, *Museu da Biodiversidade*, *Faculdade de Ciências Biológicas e Ambientais* (FCBA), Universidade Federal da Grande Dourados (UFGD), Dourados-MS, Brazil.

The quantitative analysis of populations was based on the frequency, abundance and dominance rates, considering the number of species of fruit fly caught in each trap, as in Uramoto et al. (2005). Only females of the fruit flies: *Anastrepha* spp. and *C. capitata* were considered in the calculations, because there are no keys to *Anastrepha* species based on males.

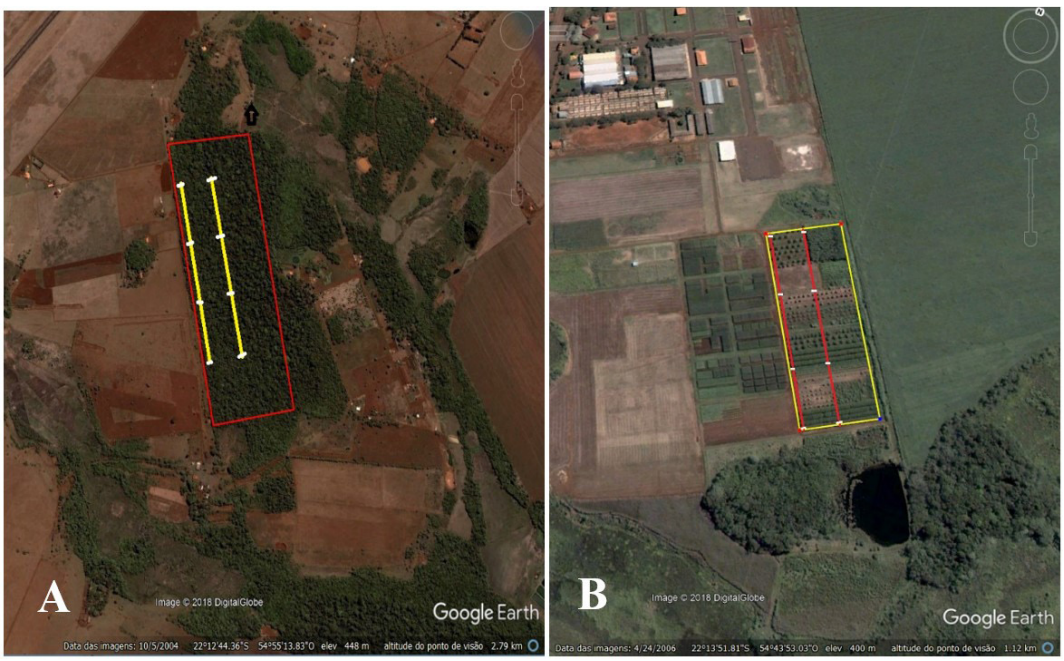

Figure 1. Environments where the fruit fly species were sampled: (A) *Reserva Florestal Fazenda Coqueiro*, and (B) Commercial orchard; both in the Dourados region-MS, Brazil (June 2005 to June 2007).

Once obtained the percentage of constancy over the 106 weeks in each environment (forest and orchard), the species were grouped into the following categories: constant (W), present in more than 50% of the weekly collections; accessory (Y) present in 25 to 49% of the collections or accidental (Z), if present in less than 25% of the collections. To classify the abundance, the limits set were employed by the confidence interval (CI) at 5% and 1% probability. The following classes were established: rare (R), number of individuals of the species smaller than the lower limit of the CI at 1% probability; dispersed (D), number of individuals between the lower limits of the confidence intervals at 1% and 5% of probability; common (C) number of individuals within the confidence interval at 5%; abundant (A), number of individuals between the upper limits of the confidence interval at 5% and 1% probability and very abundant (VA), number of individuals bigger than the upper limit of the CI at 1% probability (Uramoto et al., 2005).

Relative frequency means percentage participation of the number of individuals by species in relation to the total of individuals of all sampled species in each environment. One specie was considered dominant when it presented relative frequency superior at 1 / S, being S the total number of species in each environment. To compare the average number of individuals between the environments was applied the nonparametric test U of Mann-Whitney, because assumptions required by the parametric model were not met. Firstly, Dr. Faccenda, excluded from the statistical analysis all sampling units (McPhail traps) that did not capture anything (0 fruit fly), and the analyzes were carried out only with the so-called positive traps (those that captured at least one fruit fly). The same treatment was applied to the four environments (Forest - edge and center; Orchard - edge and center).

To verify the diversity in the environments there have been used the Shannon-Wiener with factor correction and natural logarithm (Poole, 1974) through the abundance of flies in the environments. The *Student* t test was used to verify if there is significant difference in the diversity between the studied environments using the statistical program *Past* (Hammer et al., 2001).

2.3. Edge effect on fruit fly sampling

There were six treatments: forest, orchard, forest edge, forest center, orchard edge and orchard center. To analyze whether there was a significant difference between the environments: native forest and orchard, the t test (Student) was applied. Having detected a significant difference in species richness between those two environments (forest and orchard), the t-test was subsequently applied to compare the other four treatments (sub environments): edge of the forest with its center; then edge of the orchard with the respective center. Finally, the edge of the forest was compared with that of the orchard and the center of the forest with the center of the orchard. The t test was always used comparing all treatments two by two, checking all possibilities.

3. Results

Species from six infrageneric groups (*daciformis*, *dentata*, *fraterculus*, *leptozona*, *psudoparellela*, and *striata*) of the genus *Anastrepha* Schiner 1868 were captured (275 ♂♂ + 293 ♀♀), beyond the Medfly, *Ceratitis capitata* with 1,350 adults (Table 1).

A total of 13 species (n = 1,918 adults) of fruit flies were captured in both environments. In the orchard Medfly was the most abundant species caught in the traps, with 1,343 adults. On the other hand, in the Native Forest it was represented by only seven (07) adults in the months of March, September and November (Table 2). *Ceratitis capitata* (♂♂ + ♀♀) represented 80.07% of all the fruit flies caught in the two environments. This specie was ranked as the most abundant. From the genus *Anastrepha*, 293 ♀♀ of six infrageneric groups were captured. Twelve different species of *Anastrepha* were captured in both environments, but some species occurred only in one of these (forest or orchard). In the forest were captured nine species: *Anastrepha amita* Zucchi, *A. barnesi* Aldrich, *A. daciformis* Bezzi, *A. elegans* Blanchard, *A. fraterculus* (Wiedemann), *A. montei* Lima, *A. obliqua* (Macquart), *A. pseudoparallela* (Loew) and *A. sororcula* Zucchi, being three unique of this environment: *A. amita*, *A. barnesi* and *A. elegans*. In the commercial orchard were found eight species: *A. daciformis*, *A. fraterculus*, *A. obliqua*, *A. pseudoparallela*, *A. sororcula*, *A. striata* Schiner, *A. turpiniae* Stone, and *A. zenildae* Zucchi, being the last two species exclusive to the orchard (Table 2).

After *C. capitata*, *A. sororcula* was the most abundant species, with 148 (50.51%), followed by *A. pseudoparallela*, with 49 (16.72%), *A. fraterculus* with 29 (9.89%), *A. montei* with 27 (9.20%) and *A. daciformis* with 10 (3.41%). The all other species represented approximately 10% of the fruit flies caught (Table 2).

Regarding the constancy, over the 106 samplings during the two years, it has been found that none of the species had constant incidence, not even *C. capitata*, which represented 80% of the fruit flies caught. *A. sororcula* and *C. capitata* were classified as dominant species (Table 3).

The abundance of fruit flies caught on the edge and inside of the forest, did not differ significantly. Similar patterns were found in the orchard (Table 4). However, the diversity of fruit fly species caught on traps in the ecotones (the edges) of both environments was significantly higher in compare to species diversity in the inside of each of the two ecosystems (Table 5).

4. Discussion

Anastrepha daciformis was the only species in the *daciformis* group captured, being a rare species, with only 2 adults caught in September and October, as well as *A. leptozona* (*leptozona* group), with only one adult in August. The *striata* group was also represented only by *A. striata*, with two adults in December and April. *Anastrepha montei* was the single species in the *dentata* group, captured from April to November. By other hand *A. psudoparallela* occurred in all seasons (except in Jan., Feb., Apr., Jul., and Out.). Finally, the six species of the *fraterculus* group occurred during all months of the year (Table 2).

Table 1. Total number of adult males from six infrageneric groups of *Anastrepha* and *Ceratitis capitata* (♀♀ + ♂♂) (Diptera: Tephritidae), captured over time (25 months) in two environments: Native Forest (NF) and Commercial Orchard (CO) from Dourados region, Mato Grosso do Sul, Brazil (June 2005 to June 2007).

Years	**2005**												**2006**												**2007**					
Infrageneric Species group and *C. capitata*	Jun/ 05	Jul/ 05	Aug/ 05	Sept/ 05	Oct/ 05	Nov/ 06	Dec/ 05	Jan/ 06	Feb/ 06	Mar/ 06	Apr/ 06	May/ 06	Jun/ 06	Jul/ 06	Aug/ 06	Sept/ 06	Oct/ 06	Nov/ 06	Dec/ 06	Jan/ 07	Feb/ 07	Mar/ 07	Apr/ 07	May/ 07	Jun/ 07	Species and [specimens]
daciformis group	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1 [2]
dentata group	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	1	1	1	1 [7]
fraterculus group	2	0	3	3	2	0	3	4	1	2	2	3	1	3	2	3	2	1	2	0	1	3	1	0	0	6 [44]
leptozona group	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 [1]
pseudoparallela group	0	0	0	1	0	1	1	0	0	1	0	0	1	0	1	1	0	1	1	0	0	0	0	1	0	1 [10]
striata group	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	1 [2]
Abundance ♂♂ of *Anastrepha* spp.	0	2NF	35NF 1CO	1CO	4NF 1CO	0	2NF 8CO	1NF 25CO	1CO	1NF 6CO	36CO	9CO	3NF 2CO	12 NF	19NF 2CO	8NF	18NF 1CO	10NF 3CO	14NF 1CO	1NF	1NF 1CO	2NF 10CO	9NF 1CO	14NF	10NF	166 NF + 109 CO
Abundance of *Ceratitis capitate*	0	0	1	0	9	44	27	5	2	4	2	0	0	0	1	80	452	703	16	0	1	0	1	0	0	1,350
Totals	2	2	42	5	16	45	42	35	4	14	40	12	7	16	26	93	475	719	34	1	4	15	14	16	11	1,690

Table 2. Seasonality of fruit fly species (Diptera: Tephritidae) captured in McPhail traps with food bait in a tropical native forest (NF) and in a commercial orchard (CO) in the region of Dourados-MS, Brazil (June 2005 to June 2007).

Years	2005												2006												2007			
Species and Species group (♀♀ only)	Jun/ 05	Jul./ 05	Aug./ 05	Sep./ 05	Oct./ 05	Nov./ 05	Dec./ 05	Jan./ 06	Feb./ 06	Mar./ 06	Apr./ 06	May./ 06	Jun./ 06	Jul./ 06	Aug./ 06	Sep./ 06	Oct./ 06	Nov./ 06	Dec./ 06	Jan./ 07	Feb./ 07	Mar./ 07	Apr./ 07	May./ 07	Jun. /07	Total
***daciformes* group** *A. darcoformis* Bezzi 1909	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 NF	6NF 3CO	0	0	0	0	0	0	0	0	7 NF + 3 CO=10
***fraterculus* group** *Anastrepha amita* Zucchi 1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2NF	0	0	0	0	0	0	0	0	0	2NF
A. fraterculus (Wiedemann 1830)	2NF 1CO	0	1NF	1NF	1NF	0	1CO	1CO	0	0	1CO	1CO	2NF	4NF	4NF 2CO	2NF 1CO	2NF	0	0	0	1CO	1CO	0	0	0	19NF + 10CO=19
A. turpiniae Stone 1942	0	0	0	0	0	0	1CO	3CO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4 CO
A. zenildae Zucchi 1979	0	0	0	0	0	0	0	1CO	1CO	1CO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3CO
A. sororcula Zucchi 1979	0	0	23NF	2NF	0	0	1NF 58CO	5CO	0	9CO	24CO	7CO	0	2NF	4NF	1NF	0	2NF	3NF	0	0	5CO	1NF 1CO	0	0	39NF + 109CO = 148
A. obliqua (Macquart 1835)	0	0	0	0	0	0	0	0	0	0	0	2CO	0	1NF 1CO	0	0	0	0	0	0	0	2NF	0	0	0	3NF + 3CO = 6
***leptozona* group** *A. barnesi* Aldrich 1925	0	0	5NF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5NF
***mucronota* group** *A. elegans* Blanchard 1937	1NF	0	1NF	1NF	2NF	0	0	0	0	0	0	0	0	0	0	0	1NF	0	2NF	0	0	0	0	0	0	8NF
***pseudoparallela* group** *A.pseudoparallela* (Loew 1873)	0	0	0	1NF	0	2CO	22CO	0	0	1CO	0	0	1NF	0	1NF	2NF	0	2NF	16NF	0	0	0	0	1NF	0	24NF + 25CO=49
***spatulata* group** *A. montei* Lima 1934	0	0	1NF	0	0	0	0	0	0	0	0	0	0	5NF	2NF	0	1NF	1NF	0	0	0	0	4NF	9NF 1CO	3NF	26 NF + 1CO=27
***striata* group** *A. striata* Schaner 1868	0	0	0	0	0	0	1CO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1NF	0	0	1NF + 1CO = 2
♀♀ of *Anastrepha* spp. by environment	3NF 1CO	0	31NF	5NF	3NF	2CO	1NF 83CO	10CO	1CO	11CO	25CO	10CO	3NF	12NF 1CO	11 NF 2CO	8N F 1CO	10NF 3CO	5NF	21NF	0	1CO	2NF 6CO	6NF 1CO	10NF 1CO	3NF	134NF 159CO
Number of *Anastrepha* species	2	1	5	4	2	1	5	4	1	3	2	3	2	4	4	5	4	3	3	1	1	3	3	2	1	12
Ceratitis capitata (Wied. 1824) [♂+♀]	0	0	1CO	0	9CO	44CO	27CO	5CO	2CO	2NF 2CO	2CO	0	0	0	1CO	1NF 79CO	455CO	4NF 699CO	16CO	0	0	0	1CO	0	0	7NF + 1,343CO =1,350
Abundance by Environment, and by Month	3NF 1CO	2NF	66NF 2CO	5NF 1CO	7NF 10CO	46CO	3NF 118CO	1NF 40CO	4CO	3NF 19CO	63CO	19CO	6NF 2CO	24NF 1CO	30NF 5CO	17NF 80CO	28NF 459CO	22NF 702CO	35NF 17CO	1NF	2NF 1CO	4NF 16CO	15NF 3CO	24NF 1CO	13NF	138NF + 1,502CO =1,640
Species Richness	2	1	6	4	3	2	6	5	2	4	3	3	2	4	5	6	5	4	4	0	1	3	4	2	1	13

Table 3. Population patterns of fruit fly species (Diptera: Tephritoidea) caught in McPhail traps on the edges and in the inside of two different environments (Native Forest and Commercial Orchard) in the region of Dourados-MS, Brazil (June 2005 to June 2007).

Species	Edge of Forest					Inside of Forest					Edge of Orchard					Inside of Orchard					General Analysis				
	N	F	C	A	D	N	F	C	A	D	N	F	C	A	D	N	F	C	A	D	N	F	C	A	D
A. amita	–	–	–	–	–	2	6.06	Z	C	ND	–	–	–	–	–	–	–	–	–	–	2	0.12	Z	D	ND
A. barnesi	3	2.80	Z	R	ND	2	6.06	Z	C	ND	–	–	–	–	–	–	–	–	–	–	5	0.30	Y	C	ND
A. daciformis	7	6.54	Y	C	D	–	–	–	–	–	1	0.11	Y	C	ND	2	0.34	Y	C	ND	10	0.61	Y	C	D
A. elegans	2	1.87	Z	R	ND	6	18.18	Z	VA	D	–	–	–	–	–	–	–	–	–	–	8	0.49	Y	C	D
A. fraterculus	14	13.10	Y	C	D	5	15.15	W	A	ND	5	0.54	Y	VA	ND	5	0.86	Y	VA	ND	29	1.76	Y	VA	D
A. montei	26	24.30	W	VA	D	–	–	–	–	–	–	–	–	–	–	1	0.17	Y	C	ND	27	1.64	Y	VA	D
A. obliqua	2	1.87	Z	R	ND	–	–	–	–	–	1	0.11	Y	C	ND	3	0.52	Y	C	ND	6	0.36	Y	C	ND
A pseudoparallela	22	20.56	W	VA	D	2	6.06	W	C	ND	24	2.60	Y	VA	SD	1	0.17	Y	C	ND	49	2.98	Y	VA	D
A sororcula	25	23.36	W	VA	D	15	45.45	W	VA	SD	80	8.67	Y	VA	SD	28	4.83	Y	VA	ND	148	9.01	Y	VA	SD
A. striata	–	–	–	–	–	–	–	–	–	–	1	0.11	Y	C	ND	1	0.17	Y	C	ND	2	0.12	Y	D	ND
A. turpiniae	–	–	–	–	–	–	–	–	–	–	4	0.43	Y	A	ND	–	–	–	–	–	4	0.24	Y	D	ND
A. zenildae	–	–	–	–	–	–	–	–	–	–	2	0.22	Y	C	ND	1	0.17	Y	C	ND	3	0.18	Y	D	ND
Ceratitis capitata	6	5.61	Z	C	D	1	3.03	Z	D	ND	805	87.22	W	VA	SD	538	92.76	W	VA	SD	1,350	82.17	W	VA	SD
Total	107					33					923					580					1,643				

Legend: (N) Number of female flies captured in traps, and (F) Relative frequencies (%); (C) Constancy: (W) constant, (Y) accessory, (Z) acidental; (A) Abundance: (VA) very abundant, (A) abundant, (C) common, (D) dispersed, (R) rare; (D) Dominance: (SD) super dominant, (D) dominant, (ND) non dominant.

The low catch of *C. capitata* in the forest (Table 2) can be attributed to its low preference by native host fruits. The origin center of this species is the Equatorial Africa, but in the last century a huge global process of invasion occurred (Uchoa, 2012). In Brazil, *C. capitata* presents a wide geographical distribution, being found in the Federal District (Brasília) and in 24 of the 26 Brazilian states (Except Amapá and Amazonas), infesting several fruit species of high economic importance, but in special it population increase over two preferred exotic host fruits: *Coffea* spp. (Rubiaceae) and *Terminalia catappa* L. (Combretaceae). Medfly is a cosmopolitan species, found in all Americas and several other continents, in general, attacking introduced fruit species (Uchoa, 2012; Deschepper et al., 2021; Zucchi et al., 2023).

Medfly was absolutely more abundant in the orchard, that is very close (less than 500m) from the urban area of Dourados-MS. This preference of *C. capitata* to urban areas was already recorded in the Cerrado Biome in the state of Goiás (Veloso et al., 2000). This species could have a synanthropic pattern of occurrence in Brazil, and probably worldwide.

The number of fruit fly species sampled in this study was similar to that of Canesin and Uchoa (2007) in a fragment of semi-deciduous forest in the South of Mato Grosso do Sul, 13 species of *Anastrepha* were caught in one year of sampling. However, five species found in Canesin and Uchoa (2007) were not obtained herein: *A. distincta* Greene, *A. dissimilis* Stone, *A. macrura* Hendel, *A. punctata* Hendel, and *A. serpentina* (Wied). The species *C. capitata* and *A. sororcula* that occurred as constant and dominant in this research has wide distribution and are very polyphagous. These both species were also dominant in the southwest of Mato Grosso do Sul (Uchoa et al., 2003). The data found herein allow assert that the distribution of adult of *C. capitata* per trap in the orchard was strongly aggregated, being caught mainly in traps installed in the edge. As highlighted out by Bateman (1972), the species of fruit flies may show non-dispersive movements related to the availability of fruits, because these adults need host fruits for feeding, oviposition and egg to larvae development. In the lack of fruits in the area, the movements become dispersive or migratory, because the adults migrate to areas with available fruits.

The abundance of adult fruit flies was significantly higher in the orchard in comparison to the forest, probably due to a higher density and abundance of fruits in the orchard than in the forest. The insect communities in areas of agricultural monocultures present low species richness and great abundance of the dominant species, in compare to the natural forests. Natural environments present greater stability and heterogeneity of vegetation, expressing high species richness and greater equitability in the distribution of the individuals of different species (Uchoa, 2012), because in native forests there are more habitats and niches availability to fruit fly species.

Before this research nothing was known about fruit fly species distribution in the ecotones of forests or orchards.

Table 4. Number of positive traps, mean abundance and standard deviation for the species of fruit flies (Diptera: Tephritidae) captured in McPhail traps in the edges and in the insides of different environments (Native Forest and Commercial Orchard) in the region of Dourados-MS, Brazil (June 2005 to June 2007).

Environment	N	Average*	Standard deviation
Forest			
Forest Edge	27	1.33a	0.83
Forest Inside	87	1.53a	1.11
Orchard			
Orchard Edge	71	8.27b	18.68
Orchard Inside	89	10.45b	27.96
Total	274	6.15	18.93

*Different letters in the column of averages indicate significant differences by multiple comparison test of Mann-Whitney ($p < 0.05$), at 5% significance.

Table 5. Species Richness (S) and Diversity Index (H') of Shannon-Wiener for fruit fly species (Diptera: Tephritidae) captured in McPhail traps in the edges and in the insides of two different environments in the region of Dourados-MS, Brazil (June 2005 to June 2007).

Environment	Species Richness (S)	*Diversity Index (H')	Variance	Test	Probability	Test	Probability
Forest Edge	12	2.13 a	0.00374	t (1,2) = 2.70	0.010	t (2,4) = 7.59	0.000
Forest Inside	9	1.67 b	0.0253	t (1,3) = 22.03	0.000	t (3,4) = 2.38	0.000
Orchard Edge	10	0.55 c	0.00138	t (1,4) = 22.23	0.000		
Orchard Inside	11	0.41 d	0.00225	t (2,3) = 6.83	0.000		

*Different letters in the column of the diversity Index indicate significant differences by multiple comparison test of Mann-Whitney ($p < 0.05$), at 5% of significance.

In the ecotone, as a rule, there is an overlap of the species that colonize two or more confronting ecosystems. In these transitional areas, the diversity of insects or any other group of animals that move tends to be greater, compared to the environment (central area) of each of the connected environments. This phenomenon is called edge effect, as pointed out by Naiman et al. (1989) and Kark and van Rensburg (2006).

In this research, the diversity of fruit fly species captured in the forest (from Atlantic Forest domain) is higher than in the diversified commercial orchard with 11 species of fruit trees, in both: ecotone and inside (central area). On the other hand, in the orchard, the abundance of fruit flies (total and species by species) was significantly higher where relatively few species were represented by higher number of conspecific individuals, in comparison to the forest that presented higher species richness and bigger equitability, with lowest abundance of individuals by species.

It is known that in natural environment the communities usually have many species represented by relatively few individuals, in comparison to communities of agroecosystems. In the case of orchards, with reduced vegetable complexity, Tephritidae species were represented by a large number of individuals, but distributed in a few dominant species. The results obtained in this research are congruent with those found by Bomfim et al. (2007) in which were compared fruit flies caught in environments with orchards and native forests in two counties of the state of Tocantins. They also found a highest diversity of fruit fly species in forested environments in compare to orchards.

Ceratitis capitata and *A. sororcula* were the dominant fruit fly species in both sites (native forest and orchard). The distribution of *C. capitata* per trap in the orchard was aggregated, being caught mainly in traps installed in the edges. *Anastrepha amita*, *A. barnesi* and *A. elegans* (all monophagous), were exclusive from the forest; while that *A. obliqua*, *A. turpiniae* and *A. zenildae* (all polyphagous), occurred only in the orchard. Species richness and diversity of fruit flies in the ecotones was higher than in the central areas (matrices) of the each one of the sampled adjacent environments.

We recommend the use of this knowledge (edge effect) for applying in quick inventories on fruit fly species diversity: installation of traps in the ecotones of natural forests or big commercial orchards, mainly, in places of difficult access to researchers.

Acknowledgements

We thank the *Conselho Nacional de Desenvolvimento Científico e Tecnológio* (CNPq) by the research grant (Process No. 305112/2012-0) based on research productivity awarded to M.A. Uchoa; *Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul* (FUNDECT) for the scholarship to Veruska Lopes Pereira; FUNDECT and *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES)*: Edital Chamada* FUNDECT-CAPES *Nº.* 44/2014 PAPOS-MS), and *Edital Chamada* FUNDECT-CAPES *Nº.* 12/2015-BIOTA-MS*: Ciência e Biodiversidade*, for the financial support.

References

BATEMAN, M.A., 1972. The ecology of fruit fly. *Annual Review of Entomology*, vol. 17, no. 1, pp. 493-518. http://dx.doi.org/10.1146/annurev.en.17.010172.002425.

BOMFIM, D.A., UCHOA, M.A. and BRAGANÇA, M.A.L., 2007. Biodiversity of fruit flies (Diptera, Tephritoidea) in native forests and orchards in two counties of the State of Tocantins, Brazil. *Revista Brasileira de Entomologia*, vol. 51, no. 2, pp. 217-223. http://dx.doi.org/10.1590/S0085-56262007000200012.

CANESIN, A. and UCHOA, M.A., 2007. Faunal analysis and population of fruit flies (Diptera: Tephritidae) in a fragment of semideciduous forest in Dourados, Mato Grosso do Sul, Brazil. *Revista Brasileira de Zoologia*, vol. 24, no. 1, pp. 185-190. http://dx.doi.org/10.1590/S0101-81752007000100023.

CARVALHO, F.M., MARCO-JÚNIOR, P. and FERREIRA, L.G., 2009. The Cerrado into-pieces: habitat fragmentation as a function of landscape use in the savannas of central Brazil. *Biological Conservation*, vol. 142, no. 7, pp. 1392-1403. http://dx.doi.org/10.1016/j.biocon.2009.01.031.

COELHO, J.B. and UCHOA, M.A., 2023. Fruit flies (Diptera: Tephritoidea) and parasitoids (Hymenoptera) associated with native fruit trees in the Chaco Biome. *Neotropical Entomology*, vol. 52, no. 4, pp. 629-641. http://dx.doi.org/10.1007/s13744-023-01055-z. PMid:37341901.

DESCHEPPER, P., TODD, T.N., VIRGILIO, M., DE MEYER, M., BARR, N.B. and RUIZ-ARCE, R., 2021. Looking at the big picture: worldwide population structure and range expansion of the cosmopolitan pest *Ceratitis capitata* (Diptera, Tephritidae). *Biological Invasions*, vol. 23, no. 11, pp. 3529-3543. http://dx.doi.org/10.1007/s10530-021-02595-4.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA, 2008 [viewed 12 August 2022]. *Dourados, MS* [online]. Available from: https://clima.cpao.embrapa.br/

EWERS, R.M. and DIDHAM, R.K., 2007. The effect of fragment shape and species' sensitivity to habitat edges on animal population size. *Conservation Biology*, vol. 21, no. 4, pp. 926-936. http://dx.doi.org/10.1111/j.1523-1739.2007.00720.x. PMid:17650243.

FLORES, S., GÓMEZ, E., CAMPOS, S., GÁLVEZ, F., TOLEDO, J., LIEDO, P., PEREIRA, R. and MONTOYA, P., 2017. Evaluation of mass trapping and bait stations to control *Anastrepha* (Diptera: Tephritidae) fruit flies in mango orchards of Chiapas, Mexico. *The Florida Entomologist*, vol. 100, no. 2, pp. 358-365. http://dx.doi.org/10.1653/024.100.0235.

HAMMER, O., HARPER, D.A.T. and RYAN, P.D., 2001 [viewed 26 June 2023]. Past: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* [online], vol. 4, pp. 1-9. Available from: https://palaeo-electronica.org/2001_1/past/past.pdf

KARK, S. 2017. Effects of Ecotones on biodiversity. In: B.D. ROITBERG, ed. *Reference module in life sciences*. Cham: Elsevier, 2017, pp. 142-148. http://dx.doi.org/10.1016/B978-0-12-809633-8.02290-1.

KARK, S. and VAN RENSBURG, B.J., 2006. Ecotones: marginal or central areas of transition? *Israel Journal of Ecology & Evolution*, vol. 52, no. 1, pp. 29-53. http://dx.doi.org/10.1560/IJEE.52.1.29.

MALAVASI, A. and SOUZA, F.A., 2023. Monitoramento populacional das moscas-das-frutas. In: R.A. ZUCCHI, A. MALAVASI, R. ADAIME and D.E. NAVA, eds. *Moscas-das-frutas no Brasil: conhecimento básico e aplicado*. Piracicaba: FEALQ, pp. 481-489.

MONTEIRO, L.B., NISHIMURA, G. and MONTEIRO, R.S., 2021. Natural parasitism in fruit fly (Diptera: Tephritidae) and interaction with wild hosts surrounding apple orchards adjacent to Atlantic Forest fragments in Paraná State, Brazil. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 83, e250505. http://dx.doi.org/10.1590/1519-6984.250505. PMid:34669805.

NAIMAN, R., DÉCAMPS, H. and FOURNIER, F., 1989. *The role of land/inland water ecotones in landscape management and restoration: a proposal for collaborative research*. Vendôme: Unesco, 93 p.

NORRBOM, A.L., 2010. Tephritidae (fruit flies, moscas de frutas). In: B.V. BROWN, A. BORKENT, J.M. CUMMING, D.M. WOOD, N.E. WOODLEY and M.A. ZUMBADO, eds. *Manual of Central American Diptera*. Ottawa: NRC-CNRC, vol. 2, pp. 909-954.

NORRBOM, A.L., BARR, N.B., KERR, P., MENGUAL, X., NOLAZCO, N., RODRIGUEZ, E.J., STECK, G.J., SUTTON, B.D., URAMOTO, K. and ZUCCHI, R.A., 2018. Synonymy of *Toxotrypana* Gerstaecker with *Anastrepha* Schiner (Diptera: tephritidae). *Proceedings of the Entomological Society of Washington*, vol. 120, no. 4, pp. 834-841. http://dx.doi.org/10.4289/0013-8797.120.4.834.

POOLE, R.W., 1974. *An introduction to quantitative ecology*. New York: McGraw-Hill, 532 p.

RIBEIRO, M.C., METZGER, J.P., MARTENSEN, A.C., PONZONI, F.J. and HIROTA, M.M., 2009. The Brazilian Atlantic forest: how much is left, and how is remaining forest distributed? Implications for conservations. *Biological Conservation*, vol. 142, no. 6, pp. 1141-1153. http://dx.doi.org/10.1016/j.biocon.2009.02.021.

UCHOA, M.A., 2012. Fruit flies (Diptera: Tephritoidea): biology, host plants, natural enemies, and the implications to their natural control. In: M.L. LARRAMENDY and S. SOLONESKI, eds. *Integrated pest management and pest control: current and future tactics*. Rijeka: Intech, pp. 271-300. http://dx.doi.org/10.5772/31613.

UCHOA, M.A., FERNANDES, A.S. and NAKAJIMA, J.N., 2021. Diversity of Tephritidae and Agromyzidae (Diptera: Brachycera) in flower heads of Asteraceae in the chaco. In: F. K. PERVEEN, ed. *The wonders of Diptera: characteristics, diversity, and significance for the world's ecosystems*. Rijeka: IntechOpen, pp. 18-33. http://dx.doi.org/10.5772/intechopen.96352.

UCHOA, M.A. and NICÁCIO, J., 2010. New records of Neotropical fruit flies (Tephritidae), lance flies (Lonchaeidae) (Diptera: Tephritoidea), and their host plants in the South Pantanal and adjacent areas, Brazil. *Annals of the Entomological Society of America*, vol. 103, no. 5, pp. 723-733. http://dx.doi.org/10.1603/AN09179.

UCHOA, M.A., OLIVEIRA, M.P. and ALMEIDA, L.B.M., 2023. Moscas-das-frutas, suas plantas hospedeiras e parasitoides no estado de Mato Grosso do Sul. In: R.A. ZUCCHI, A. MALAVASI, R. ADAIME and D.E. NAVA, eds. *Moscas-das-frutas no Brasil: conhecimento básico e aplicado*. Piracicaba: FEALQ, pp. 177-193.

UCHOA, M.A., OLIVEIRA, I., MOLINA, R.M.S. and ZUCCHI, R.A., 2003. Populational fluctuation of frugivorous flies (Diptera: Tephritoidea) in two orange groves in state of Mato Grosso do Sul, Brazil. *Neotropical Entomology*, vol. 32, no. 1, pp. 19-25. http://dx.doi.org/10.1590/S1519-566X2003000100003.

URAMOTO, K., WALDER, J.M.M. and ZUCCHI, R.A., 2005. Análise quantitativa e distribuição de populações de espécies de *Anastrepha* (Diptera: Tephritidae) no campus Luiz de Queiroz, Piracicaba-SP. *Neotropical Entomology*, vol. 34, no. 1, pp. 33-39. http://dx.doi.org/10.1590/S1519-566X2005000100005.

VELOSO, V.R.S., FERNANDES, P.M. and ZUCCHI, R.A., 2000. Goiás. In: A. MALAVASI and R. A. ZUCCHI, eds. *Moscas-das-frutas de importância econômica no Brasil: Conhecimento básico e aplicado*. Ribeirão Preto: Holos-FAPESP, pp. 247-252.

ZUCCHI, R.A., 2023. Taxonomia de moscas-das-frutas com ênfase no gênero *Anastrepha*. In: R.A. ZUCCHI, A. MALAVASI, R. ADAIME and D.E. NAVA, eds. *Moscas-das-frutas no Brasil: conhecimento básico e aplicado*. Piracicaba: FEALQ, pp. 45-57.

ZUCCHI, R.A. and MORAES, R.C.B. 2023 [viewed 26 March 2023]. *Fruit flies in Brazil -Anastrepha species their host plants and parasitoids* [online]. Available from: www.lea.esalq.usp.br/anastrepha/

ZUCCHI, R.A., MALAVASI, A., ADAIME, R. and NAVA, D.E., 2023. *Moscas-das-frutas no Brasil: conhecimento básico e aplicado*. Piracicaba: Fealq, 307 p.