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Fruit flies (Diptera, Tephritidae) and their parasitoids on cultivated and wild hosts in the Cerrado-Pantanal ecotone in Mato Grosso do Sul, Brazil

Tiago Ledesma Taira[1], Alfredo Raúl Abot[1], José Nicácio[2], Manoel Araécio Uchôa[2], Sérgio Roberto Rodrigues[1] & Jorge Anderson Guimarães[3]

[1]Universidade Estadual de Mato Grosso do Sul, Rodovia Aquidauana-CERA, km 12, 79200–000 Aquidauana-MS, Brasil. tiago_taira@hotmail.com
[2]Universidade Federal da Grande Dourados, Av. Guaicurus km 12, 79804–970 Dourados-MS, Brasil.
[3]Embrapa Hortaliças, Rodovia Brasília/Anápolis BR 060, Km 09, 70359–970 Gama-DF, Brasil.

ABSTRACT. Fruit flies (Diptera, Tephritidae) and their parasitoids on cultivated and wild hosts in the Cerrado-Pantanal ecotone in Mato Grosso do Sul, Brazil. Information on frugivorous flies in cultivated or wild host plants and their parasitoids in the Cerrado-Pantanal ecotone in Aquidauana, Mato Grosso do Sul is presented and discussed. Fruit fly samples were collected weekly in specific fruit trees, and McPhail® traps were installed in the same trees for a period of two years. The fruit flies infested ripe and unripe fruits of *Averrhoa carambola* L., *Schoepfia* sp., *Psidium guajava* L. and *Pouteria torta* (Mart.) Radlk and mature fruits of *Anacardium occidentale* L. and *Inga laurina* (Sw.) Willd. Nineteen fruit fly species were obtained with the combination of sampling methods (collecting fruits and trapping), nine of them obtained with both methods, five found only in fruits and five only in traps. This is the first record of *Anastrepha striata* Schiner in a species of Sapotaceae, as well as for *A. castanea* Norrbom and *A. daciformes* Bezzi in *Schoepfia* sp. (Olacaceae), and for *A. distincta* Greene in fruits of *P. guajava* in the state of Mato Grosso do Sul. Fruit collections simultaneously associated with capture of fruit flies by McPhail traps in the same host plants are essential to understand the diversity of fruit flies and their relationship with hosts and parasitoids. Species of Braconidae and Pteromalidae were recovered, where *Doryctobracon areolatus* (Szépligeti) was the most abundant parasitoid in larvae of tephritids infesting both cultivated and wild host fruits.

KEYWORDS. Insecta; Mediterranean fruit fly; quarantine pests; Tephritoidea.

Tropical fruits are important for developing regions due to their economic and nutritional characteristics. About 90% of these fruits produced worldwide are consumed in the countries where they are produced, and the rest is exported *in natura* or processed. The value of tropical fruit production was estimated at 43.7 billion dollars in 2008 (FAO 2009). Brazil is the third largest producer of fruits after China and India, with annual production of about 43 million tons (INCT 2009).

Frugivorous fruit flies, especially species of Tephritidae, which in the larval stage consume fruit pulp from different botanical families (Zucchi 2000a; Gonçalves *et al*. 2006; Garcia & Norrbom 2011; Ronchi-Teles *et al.* 2011), have been a major problem for world fruit production. Although known as fruit flies, some species of larval Tephritoidea can feed on flower buds, flowers, buds, leaves, seeds and roots (Evstigneev 2011; Khaghaninia *et al*. 2011; Sabedot-Bordin *et al*. 2011; Uchôa 2012).

The genera of greatest importance to Brazil are *Anastrepha* Schiner, 1868, *Ceratitis* Macleay, 1829, *Bactrocera* Macquart, 1835 and *Rhagoletis* Loew, 1862, with an emphasis on the first two due to the large number of hosts which they utilize (Zucchi 2000b, 2007). In Mato Grosso do Sul, the occurrence of *Ceratitis capitata* (Wiedemann, 1824) has been reported along with nearly 30 species of *Anastrepha* (Uchôa-Fernandes *et al*. 2002, 2003a; Rodrigues *et al*. 2006; Canesin & Uchôa-Fernandes *et al*. 2007; Uchôa & Nicácio 2010).

Losses to Brazilian fruticulture related to these pests vary between 120 and 200 million dollars annually, due to high cost of control (Felix *et al*. 2009) and phytosanitary barriers of importing countries (Paranhos *et al*. 2007). Knowledge of the relationship between frugivorous tephritids and their hosts is critical for the control of pest species (Nicácio & Uchôa 2011). However, it is important to know the phenology of these fruit trees, mainly native and/or non-cultivated species, since tephritid pests may use them to maintain their populations during the offseason of planted fruit crops.

Several studies have been conducted with Tephritidae using traps, especially those of the model McPhail®, used worldwide for monitoring and/or control of these insects (Rousse *et al*. 2005; Canesin & Uchôa-Fernandes *et al*. 2007; Jemâa *et al*. 2010). However, when seeking to understand the diversity of economically important fruit flies it is necessary to conduct intensive analyses in the fruits themselves (Zucchi 2000b), since not only is the association between the fly species with the host plant verified, but there is also identification of its parasitoids.

The objective of this study was to understand the interaction between fruit flies (Tephritidae) and their parasitoids in cultivated and wild hosts, based on survey of plant reproductive structures and use of McPhail® traps, in an area of the Cerrado-Pantanal ecotone of Mato Grosso do Sul, Brazil.

MATERIAL AND METHODS

The study was conducted on the campus of the State University of Mato Grosso do Sul (UEMS) in Aquidauana and in an adjacent area during two years, from June 27, 2009 to June 26, 2011. The climate, according to the Köppen classification, is type Aw (Tropical warm – wet) with rainy summer and dry winter, with annual precipitation of 1,250 to 1,500 mm and an average temperature of 26°C. The region is comprised of native vegetation, large areas of pasture (cultivated grasses), small domestic orchards and an experimental area of fruit and annual crops of the UEMS, where guava, mango, banana and coconut are grown along with various plant species.

McPhail® traps, baited with 300 ml of 5% hydrolzed corn protein (Uchôa-Fernandes *et al*. 2003b), were used in association with collecting of plant reproductive structures from wild and cultivated fruit species (Table I). The bait was renewed weekly when the captured flies were also collected, which were placed in labeled vials containing 80% ethanol. Each fruit species was represented by one plant and in each plant one trap was installed at 1.7 m above the ground. The reproductive structures were collected concurrently with the collection of material from the traps. Phenological phases were classified as bud, flower, unripe fruit and ripe fruit. The quantity of reproductive structures was dependent on the availability in the field (Table II). Ripe fruits were randomly collected from the plant in which the trap was installed, and in previous stages fruits were also collected from plants of the same species surrounding the plant in which the trap was installed.

The reproductive structures were placed on wooden pallets with a sombrite screen, with 1 cm^2 openings. The pallets were placed inside black plastic containers measuring 57x37x12 cm, containing water at a depth of 2 cm to retain third instar larvae in the case they abandoned the fruits (Uchôa-Fernandes & Zucchi 1999).

The recipients were monitored daily between 7h00 and 17h00 to avoid death of the larvae by drowning. Larvae were transferred to transparent plastic vials (200 mL), one used as a base and the other as a lid, secured with adhesive tape. A 4 cm layer of sterilized sand moistened with distilled water was placed on the base. The recovered adults and their parasitoids were sacrificed 24 hours after emergence and were stored in 80% ethanol for later identification. The Tephritidae specimens were identified by Prof. Dr. Manoel A. Uchôa (Federal University of Grande Dorados (UFGD), Dourados, Mato Grosso do Sul, Brazil) and the parasitoids by Dr. Jorge Anderson Guimarães (*Embrapa Hortaliças*, Brasília, Distrito Federal, Brazil). Some Tephritidae specimens are deposited in the entomology collection of the UEMS and at the Museum of Biodiversity, School of Biological and Environmental Sciences of the UFGD; the parasitoid specimens are stored at *Embrapa Hortaliças*.

Table II. Quantity of reproductive structures and fruit mass from selected fruit plant species collected in the Cerrado-Pantanal ecotone, Aquidauana, Mato Grosso do Sul, Brazil (June 2009 to June 2011).

Host	Phenological stage					
	Bud	Flower	Unripe fruit		Ripe fruit	
			Quantity	Mass (kg)	Quantity	Mass (kg)
Anacardium occidentale	3	5	15	1.32	27	10.82
Annona muricata	–	28	67	15.80	6	2.20
Averrhoa carambola	1	7	17	2.29	68	39.30
Citrus sinensis	–	–	44	21.06	34	29.47
Psidium guajava	–	–	45	12.89	59	112.17
Buchenavia tomentosa	3	4	8	0.94	11	1.86
Dipteryx alata	8	3	68	10.97	5	0.95
Inga laurina	6	3	46	2.33	22	1.93
Pouteria torta	12	3	23	3.06	9	12.30
Schoepfia sp.	–	5	3	0.49	10	3.14

The absolute and relative abundances of Tephritidae species were expressed in relation to total females recovered, while the absolute abundance of parasitoids was in relation to the total number of individuals. For analysis of the population fluctuation of frugivorous fly species and the quantity (weight) of fruit, the data obtained per week was used, i.e., the means from 4–5 repetitions per month. The parasitism percentage was calculated according to the equation: [number of parasitoids recovered*100/Number of larvae (3^{rd} instar) of Tephritidae].

RESULTS

Of the reproductive structures from the fruit plants assessed, only the fruits themselves were infested by tephritids. Of these, 6,746 larvae were obtained in fruits of *Anacardium*

Table I. Fruit plants sampled and their locations in the Cerrado-Pantanal ecotone, Aquidauana, Mato Grosso do Sul, Brazil (June 2009 to June 2011).

Hosts	Family	Species	Common name	Origin	Geographical Location	Elevation
Cultivated	Anacardiaceae	*Anacardium occidentale* L., 1753	Cashew	Native	20°26’14”S, 55°39’41”W	201 m
	Annonaceae	*Annona muricata* L., 1753	Soursop	Exotic	20°29’56”S, 55°37’05”W	162 m
	Oxalidaceae	*Averrhoa carambola* L., 1753	Starfruit	Exotic	20°28’59”S, 55°38’05”W	181 m
	Rutaceae	*Citrus sinensis* (L.) Osbeck, 1765	Orange	Exotic	20°29’47”S, 55°36’41”W	153 m
	Myrtaceae	*Psidium guajava* L., 1753	Guava	Native	20°26’27”S, 55°39’49”W	195 m
Non-cultivated	Combretaceae	*Buchenavia tomentosa* Eichler, 1866	Tarumarana	Native	20°26’12”S, 55°39’22”W	180 m
	Fabaceae	*Dipteryx alata* Vogel, 1837	Cumbaru	Native	20°27’32”S, 55°39’48”W	208 m
	Fabaceae	*Inga laurina* (Sw.) Willdenow, 1806	Ingá	Native	20°26’12”S, 55°39’35”W	209 m
	Sapotaceae	*Pouteria torta* (Mart.) Radlk, 1882	Guapeva	Native	20°26’04”S, 55°39’31”W	227 m
	Schoepfiaceae	*Schoepfia* sp.	Chora-menina	Native	20°26’08”S, 55°39’33”W	216 m

occidentale L., *Averrhoa carambola* L., *Inga laurina* (Sw.) Willd., *Pouteria torta* (Mart.) Radlk, *Psidium guajava* L. and *Shoepfia* sp., which resulted in 4,424 adults (67.74% viability), with a sex ratio of 1:1. The sum of larvae in fruits of *A. carambola* (2,372), *P. guajava* (2,711) and *P. torta* (1,635) accounted for 99.58% of the total (Table III).

Larvae were recovered in unripe and ripe fruits of *A. carambola*, *P. torta*, *P. guajava* and *Shoepfia* sp. and ripe fruits of *A. occidentale* and de *I. laurina*. Of the total number of larvae in *A. carambola* fruits, 98.61% were obtained from ripe fruit and they presented viability of 71.13%, where in unripe fruits larval viability was 62.50%. Among larvae collected from *P. guajava* fruits, 86.28% were obtained from ripe fruits with viability of 60.00%, while those from unripe fruit presented viability of 76.00%. In fruits of *P. torta*, 91.38% of larvae were obtained from ripe fruits with viability of 73.57%, lower than the viability of larvae obtained from unripe fruits (Table III).

Fruits of *P. guajava*, *A. carambola* and *P. torta* presented the highest rates of infestation with 20.48, 56.24 and 97.27 larvae kg^{-1}, respectively. Contrarily, the fruits of *A. occidentale*, *I. laurina* and *Shoepfia* sp. which had the lowest number of larvae showed infestations of 0.16, 2.11 and 4.68 larvae kg^{-1}, respectively.

In all the traps associated with fruit trees at least one frugivorous tephritid specimen was captured (Table III). Of the 378 flies captured with this method, 113 were females and 265 males, resulting in a 1:2 sex ratio (♀:♂). Of the total number of flies captured, 0.79% were acquired from traps installed in *A. occidentale*; 5.82% from *Annona muricata* L.; 14.81% from *A. carambola*; 2.65% from *Buchenavia tomentosa* Eichler; 0.26% from *Citrus sinensis* (L.) Osbeck; 3.97% from *Dipterix alata* Vogel; 2.38% from *I. laurina*; 9.26% from *P. torta*; 58.73% from *P. guajava* and 1.32% from *Shoepfia* sp. (Table III).

Nineteen fruit fly species were obtained with the combination of sampling methods (collecting fruits and trapping), nine of them obtained with both methods, five found only in fruits and five only in traps (Table IV). In relation to the fruit samples, *A. carambola* presented the greatest number of positive samples (818), followed by *P. guajava* (767) and *P. torta* (599). These same fruits showed a larger number of associated fly species, where eight species were found in *P. guajava*, five in *P. torta* and four in *A. carambola* (Table IV).

The increased number and diversity of fruit fly species in the collecting method using traps were confirmed in those installed in *P. guajava* (45.13% of the species; 6 species), followed by those installed in *A. carambola* (22.12% of the species; 4 species) and *P. torta* (12.39% of the species; 5 species) (Table IV).

Of the 14 species associated with fruits, five infested both unripe and ripe fruits, seven occurred only in ripe fruits and two were found only in unripe fruits (Table V). More than 90% of fruit flies from fruits of *A. carambola*, *I. laurina*, *P. torta* and *P. guajava* were acquired from larvae infesting ripe fruits. In *Shoepfia* sp., 75% of the flies were also associated with this maturation phase (Table V).

Anastrepha obliqua occurred in July and August of 2009, during seven months of 2010 and six months of 2011 in *A. carambola*, presenting three population peaks (Fig. 1). This species also occurred in *P. guajava* from November 2009 to February 2010 and in April 2010. *Ceratitis capitata* infested *A. carambola* fruits during six months of 2010 and five of 2011, with the highest average number of larvae in July 2010

Table III. Sampling methods of larvae and adults of Tephritidae associated with cultivated and wild fruit plants in the Cerrado-Pantanal ecotone, Aquidauana, Mato Grosso do Sul, Brazil (June 2009 to June 2011).

Host	Sampling method	Maturation state of the fruit	Number of Larvae	Number of females	Number of males	Viability (%)
Anacardium occidentale	Fruit	Ripe	2	–	–	0
	Trap	–	–	1	2	–
Annona muricata	Trap	–	–	10	12	–
Averrhoa carambola	Fruit	Unripe	33	13	7	62.50
		Ripe	2,339	805	794	71.13
	Trap	–	–	25	31	–
Buchenavia tomentosa	Trap	–	–	3	7	–
Citrus sinensis	Trap	–	–	0	1	–
Dipteryx alata	Trap	–	–	2	13	–
Inga laurina	Fruit	Ripe	9	2	7	100.00
	Trap	–	–	5	4	–
Pouteria torta	Fruit	Unripe	141	59	55	80.85
		Ripe	1,494	540	543	73.57
	Trap	–	–	14	21	–
Psidium guajava	Fruit	Unripe	150	64	50	76.00
		Ripe	2,561	703	773	60.00
	Trap	–	–	51	171	–
Schoepfia sp.	Fruit	Unripe	4	1	2	75.00
		Ripe	13	3	3	46.15
	Trap	–	–	2	3	–
Total	Fruit	–	6,746	2190	2234	67.74
	Trap	–	–	113	265	–

Table IV. Abundance and relative percentage of fruit flies (Diptera, Tephritidae) obtained in McPhail® traps and larvae infesting cultivated and wild fruits in the Cerrado-Pantanal ecotone, Aquidauana, Mato Grosso do Sul, Brazil (June 2009 to June 2011).

Tribe/Species	Hosts																		N	%
	Ao		Am		Ac		Bt		Da		Il		Pt		Pg		Sh			
	T	F	T	F	T	F	T	F	T	F	T	F	T	F	T	F	T	F		
Toxotrypanini																				
Anastrepha alveatoides Blanchard, 1961	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1	0.04
Anastrepha castanea Norrbom, 1998	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1***	1	0.04
Anastrepha daciformes Bezzi, 1909	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3***	3	0.13
Anastrepha distincta Greene, 1934	–	–	–	–	–	–	–	–	–	–	–	2	1	–	–	1**	–	–	4	0.17
Anastrepha fraterculus (Wiedemann, 1830)	–	–	–	–	–	–	–	–	–	–	–	–	2	–	7	108	–	–	117	5.08
Anastrepha hamata Loew, 1873	–	–	–	–	–	–	–	–	–	–	–	–	6	–	–	–	1	–	7	0.30
Anastrepha leptozona Hendel, 1914	–	–	1	–	–	–	1	–	1	–	–	–	4	554	–	–	–	–	561	24.35
Anastrepha montei Lima, 1934	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1	0.04
Anastrepha obliqua (Macquart, 1835)	–	–	3	–	11	488	–	–	–	–	–	–	–	–	17	8	–	–	527	22.88
Anastrepha rheediae Stone, 1942	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1	–	2	0.09
Anastrepha serpentina (Wiedemann, 1830)	–	–	–	–	–	–	–	–	–	–	–	–	–	31	–	–	–	–	31	1.35
Anastrepha sororcula Zucchi, 1979	1	–	3	–	5	13	1	–	–	–	1	–	–	–	17	279	–	–	320	13.89
Anastrepha striata Schiner, 1868	–	–	–	–	–	5	–	–	–	–	–	–	–	4*	8	291	–	–	308	13.37
Anastrepha turpiniae Stone, 1942	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	66	–	–	68	2.95
Anastrepha zenildae Zucchi, 1979	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	7	–	–	8	0.35
Anastrepha zernyi Lima, 1934	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	2	0.09
Anastrepha sp.1	–	–	–	–	–	–	–	–	–	–	–	–	–	8	–	–	–	–	8	0.35
Anastrepha sp.2	–	–	–	–	–	–	–	–	–	–	2	–	1	–	–	–	–	–	3	0.13
Ceratitidini																				
Ceratitis capitata (Wiedemann, 1824)	–	–	3	–	8	312	–	–	–	–	–	–	–	–	1	7	–	–	331	14.37
Total individuals	1	–	10	–	25	818	3	–	2	–	5	2	14	599	51	767	2	4	2,303	100.00
Total species	1	–	4	–	4	4	3	–	2	–	3	1	4	5	6	8	2	2	19	

T – Trap; F – Fruit; *First record for the botanical family in Brazil; **First record for the state of Mato Grosso do Sul (Brazil); ***First record for the host; Ao – *Anacardium occidentale*; Am – *Annona muricata*; AC – *Averrhoa carambola*; Bt – *Buchenavia tomentosa*; Da – *Dipteryx alata*; Il – *Inga laurina*; Pt – *Pouteria torta*; Pg – *Psidium guajava* and Sh – *Schoepfia* sp.

Table V. Abundance and relative percentage of fruit flies (Diptera, Tephritidae) obtained in unripe and ripe fruits from cultivated and wild fruit plants in the Cerrado-Pantanal ecotone, Aquidauana, Mato Grosso do Sul, Brazil (June 2009 to June 2011).

Taxon	Ac				Il				Pt				Pg				Sh			
	Unripe		Ripe		Unripe		Ripe		Unripe		Ripe		Unripe		Ripe		Unripe		Ripe	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Toxotrypanini																				
Anastrepha castanea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	25.00
Anastrepha daciformes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	25.00	2	50.00
Anastrepha distincta	–	–	–	–	–	–	2	100.00	–	–	–	–	–	–	1	0.13	–	–	–	–
Anastrepha fraterculus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	108	14.03	–	–	–	–
Anastrepha leptozona	–	–	–	–	–	–	–	–	49	8.18	505	84.31	–	–	–	–	–	–	–	–
Anastrepha obliqua	9	1.10	479	58.56	–	–	–	–	–	–	–	–	–	–	8	1.04	–	–	–	–
Anastrepha serpentina	–	–	–	–	–	–	–	–	–	–	31	5.17	–	–	–	–	–	–	–	–
Anastrepha sororcula	–	–	13	1.59	–	–	–	–	–	–	–	–	–	–	279	36.38	–	–	–	–
Anastrepha striata	1	0.12	4	0.49	–	–	–	–	–	–	4	0.67	64	8.34	227	29.60	–	–	–	–
Anastrepha turpiniae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	66	8.60	–	–	–	–
Anastrepha zenildae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7	0.91	–	–	–	–
Anastrepha zernyi	–	–	–	–	–	–	–	–	2	0.33	–	–	–	–	–	–	–	–	–	–
Anastrepha sp.1	–	–	–	–	–	–	–	–	8	1.34	–	–	–	–	–	–	–	–	–	–
Ceratitidini																				
Ceratitis capitata	3	0.37	309	37.76	–	–	–	–	–	–	–	–	–	–	7	0.91	–	–	–	–
Total individuals	13	1.59	805	98.41	–	–	2	100.00	59	9.85	540	90.15	64	8,34	703	91.66	1	25.00	3	75.00
Total species	3		4		–		1		3		3		1		8		1		2	

Ac – *Averrhoa carambola*; Il – *Inga laurina*; Pt – *Pouteria torta*; Pg – *Psidium guajava* and Sh – *Schoepfia* sp.

and February 2011 (Fig. 1). In *P. guajava* this species was obtained from December 2010 to February 2011.

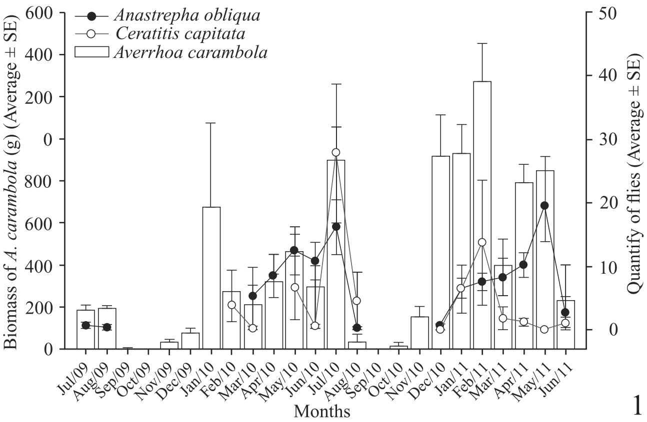
Larvae of *A. striata* obtained from fruits of *P. guajava* were recovered from August to December 2009, with a population peak in November, occurring during eight months of 2010 and five in 2011 (Fig. 2). These larvae were also obtained in November and December of 2010 infesting *P. torta* fruits and in March, April and June of 2011 in *A. carambola*.

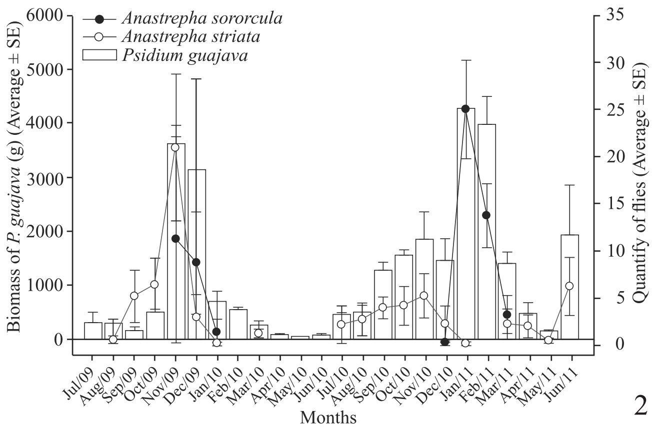
Anastrepha sororcula obtained from larvae infesting fruits of *P. guajava* presented a population peek in January 2010 (Fig. 2) and occurred in March, April and June of 2011 in *A. carambola* fruits.

A total of 215 parasitoids were recovered from the families Braconidae (96.74%) and Pteromalidae (3.26%). Braconidae were represented by *Doryctobracon areolatus* (Szépligeti, 1911), *Utetes anastrephae* Viereck, 1913 and *Opius bellus* Gahan, 1930, while Pteromalidae was represented by an unidentified species (Table VI).

Parasitism of larvae in *A. carambola* fruit was 5.88% in 2009, 5.61% in 2010 and 2.07% in 2011. In *P. guajava* it was 3.73% in 2009, 0.71% in 2010 and 4.42% in 2011. In *P. torta*, parasitism of 1.48% was observed in 2010 (Table VI). Most parasitoids were acquired from larvae infesting mature fruits, except one specimen of *D. areolatus* that parasitized larvae infesting unripe fruit of *A. carambola*.

Doryctobracon areolatus was the most abundant (82.79%) and generalist among the parasitoids obtained, parasitizing larvae acquired from *A. carambola*, *P. guajava* and





Figs. 1–2. Population fluctuation of larvae of *Ceratitis capitata*, *Anastrepha obliqua* and fruit biomass of *Averrhoa carambola* (1), and *Anastrepha sororcula*, *Anastrepha striata* and fruit biomass of *Psidium guajava* (2) in the Cerrado-Pantanal ecotone, Aquidauna, Mato Grosso do Sul, Brazil, from July 2009 to June 2011.

Table VI. Total number (N) of Tephritidae larvae (Diptera, Tephritoidea), parasitoids and parasitism percentage, in fruits of *Averrhoa carambola*, *Psidium guajava* and *Pouteria torta*, collected in the Cerrado-Pantanal ecotone, Aquidauana, Mato Grosso do Sul, Brazil (June 2009 to June 2011).

Variables evalauted	2009							2010												2011						N
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Averrhoa carambola																										
Tephritidae	6	8	2	–	–	1	–	–	30	72	140	220	140	536	47	–	–	–	9	263	297	101	242	221	37	2372
Braconidae																										
Doryctobracon areolatus (Szépligeti, 1911)	–	–	–	–	–	1	–	–	–	14	12	12	5	7	1	–	–	–	–	–	2	2	14	1	–	71
Parasitism (%)	–	–	–	–	–	100	–	–	–	19.44	8.57	5.45	3.57	1.31	2.13	–	–	–	–	–	0.67	1.98	5.79	0.45	–	–
Utetes anastrephae Viereck, 1913	–	–	–	–	–	–	–	–	–	–	4	3	1	1	–	–	–	–	–	–	3	–	1	–	–	13
Parasitism (%)	–	–	–	–	–	–	–	–	–	–	2.86	1.36	0.71	0.19	–	–	–	–	–	–	1.01	–	0.41	–	–	–
Opius bellus Gahan, 1930	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	1
Parasitism (%)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.34	–	–	–	–	–
Pteromalidae																										
Pteromalidae sp. 1	–	–	–	–	–	–	–	–	–	–	–	–	–	7	–	–	–	–	–	–	–	–	–	–	–	7
Parasitism (%)	–	–	–	–	–	–	–	–	–	–	–	–	–	1.31	–	–	–	–	–	–	–	–	–	–	–	–
Psidium guajava																										
Tephritidae	–	–	7	43	87	659	412	35	10	14	–	–	–	27	21	36	47	63	27	749	307	68	32	5	62	2711
Braconidae																										
Doryctobracon areolatus	–	–	–	–	–	17	14	–	–	–	–	–	–	–	–	–	–	2	–	42	10	–	–	–	–	85
Parasitism (%)	–	–	–	–	–	2.58	3.40	–	–	–	–	–	–	–	–	–	–	3.17	–	5.61	3.26	–	–	–	–	–
Utetes anastrephae	–	–	–	–	–	14	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	16
Parasitism (%)	–	–	–	–	–	2.12	–	–	–	–	–	–	–	–	–	–	–	–	–	0.27	–	–	–	–	–	–
Pouteria torta																										
Tephritidae	–	–	–	–	–	44	28	10	–	–	–	–	–	–	1	–	270	1057	225	–	–	–	–	–	–	1635
Braconidae																										
Doryctobracon areolatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	17	3	–	–	–	–	–	–	22
Parasitism (%)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.74	1.60	1.33	–	–	–	–	–	–	–

P. torta. The parasitism percentage per insect in larvae obtained from *A. carambola* was 2.99%, 3.14% in *P. guajava* and 1.35% in *P. torta*. This parasitoid was recovered in November and December of 2009, from March to August and October to December of 2010 and from January to May of 2011, most expressively in March 2010 when the parasitism percentage of larvae obtained from *A. carambola* was 19.44% (Table VI).

Utetes anastrephae was the second most abundant species parasitizing larvae from *P. guajava* and *A. carambola*, while *Opius bellus* and Pteromalidae sp.1 were associated only with tephritid larvae in *A. carambola* (Table VI).

DISCUSSION

The higher number of tephritids obtained from fruits compared to that from traps was probably due to the greater attractiveness of the fruit, since the fruit flies utilized them to reproduce, whereas the bait used in the traps is only a food source for the adults. Another factor that may imply an increased abundance in fruits may be related to the features of each sampling method, since in the fruits one or more females may oviposit at each visit, and a female has the ability to oviposit over 200 eggs during her life in different periods and fruits, in the trap, when captured, each fly is sampled once. The attraction of females to the fruit is enhanced by color and by the release of volatiles, as highlighted by Malo *et al*. (2005) and Zarbin *et al*. (2009).

Montes *et al*. (2011) obtained a 1:2 sex ratio (♀:♂) in areas with cucurbits, as in this study, however it appears that there is no common standard with regards to the sex ratio of tephritids captured in traps baited with proteins, as verified by various authors who obtained a higher number of females (Montes & Raga 2006; Dutra *et al*. 2009; Trindade & Uchôa 2011; Santos *et al*. 2011). The variation of the number of males and females in the traps may likely be related to the number of samples of each sex in the field or that females are feeding and copulating in areas near the trap and then moving towards the oviposition sites.

The fact that frugivorous fruit flies developing in unripe fruits of *P. torta*, *P. guajava* and *Shoepfia* sp. had greater viability than in mature fruits can be explained by the lower number of larvae obtained from unripe fruits. However, this demonstrates that although unripe fruits were not preferred for oviposition, they allowed for successful reproduction of the species.

Pereira-Rêgo *et al*. (2011) obtained larvae of *A. fraterculus* from unripe, semiripe and ripe fruits of *Psidium cattleyanum* var. lucidum (Mart. ex O. Berg) Kiaersk. (*araçá-amarelo*), *P. cattleyanum* (Mart. ex O. Berg) Kiaersk. (*araçá-vermelho*) and *P. guajava.* These larvae transformed into adults similar in relation to pupal weight and wing area within each botanical species, independent of the stage of ripeness. Carvalho *et al*. (1998), in studies of the biology of *Anastrepha obliqua* (Macquart, 1835), confirmed that peak oviposition is attained during the reproduction period. In the present study, the infestation of unripe fruit may also be due to concurrence with the peak of oviposition of this species during this maturation state. The ability to infest unripe fruits by some fruit fly species is a fact that may contribute to their predominance in some hosts. Moura & Moura (2006) confirmed that *C. capitata* was the only dominant and constant species in guava fruits and reported that this association may be due to the fact that it is the only species that fully infested the fruits.

The high tephritid infestation confirmed in the present study in fruits of *P. guajava* and *A. carambola*, was different than that observed by Sá *et al*. (2008) in the fruit production center in Anagé, Bahia, Brazil, where fruits of *A. carambola* were not attacked and infestation in *P. guajava* was reduced, which reinforces the need for regional studies.

Anastrepha alveatoides Blanchard, 1961 occurred only in the trap installed in *D. alata*, indicating that a specimen of sea lemon (*Ximenia americana* L.), its only reported host in Pantanal, Brazil (Uchôa & Nicácio 2010), is likely near the plant of *D. alata*. The infestation of *Shoepfia* sp. fruits by *Anastrepha castanea* Norrbom, 1998 and *A. daciformes* Bezzi, 1909 constitutes the first record for this host. However, these fly species are not the only ones who use it for oviposition, since Uchôa and Nicácio (2010) reported infestations by *A. macrura*, *A. sororcula* and *A. zernyi* in fruits of this species in the same region.

The presence of *Anastrepha distincta* Greene, 1934 in the study area, captured in the trap installed in *P. torta* and in ripe fruits of *I. laurina* and *P. guajava* was also observed by Uchôa and Nicácio (2010) in association with fruits of *I. laurina* in the same region. The association of this fly with fruits of *P. guajava* in the state of Mato Grosso do Sul, however, has not been reported before.

Although *Anastrepha fraterculus* (Wiedemann, 1830) was obtained in traps installed in *P. torta* and *P. guajava*, this species infest only fruits of Myrtaceae. In the state of São Paulo, Raga *et al*. (2005) found that this species is dominant in fruits of *P. guajava*.

Anastrepha hamata (Loew, 1873) was obtained in traps installed in *P. torta* and *Shoepfia* sp., not occurring in any fruit of the surveyed plants. According to Zucchi (2000a), the host of this tephritid species is unknown. The association of *Anastrepha leptozona* Hendel, 1914 with fruits of *P. torta* was also verified by Uchôa and Nicácio (2010) who conducted studies in the Pantanal region of Mato Grosso do Sul.

The capture of *Anastrepha montei* Lima, 1934 in the trap installed in *A. carambola* may be due to the abundant regional production of *Manihot esculenta* Crantz, which according to Zucchi *et al*. (2000a) is a host of this fly species.

Predominance of *Anastrepha obliqua* in *A. carambola* fruits was also observed by Souza-Filho *et al*. (2000) and Uramoto *et al*. (2004) in the state of São Paulo. Occurrence of *Anastrepha serpentina* (Wiedemann, 1830) in fruits of *P. torta* seems common in the region, since it was also verified by Uchôa and Nicácio (2010).

The presence of *Anastrepha sororcula* Zucchi, 1979 in more than one-half of the installed traps was due to the fact that *P. guajava* is common in the region and also resultant of the existence of an orchard of this fruit plant in the experimental unit of the UEMS Fruticulture. This tephritid is the main species infesting guava fruits in Mato Grosso do Sul (Uchôa & Nicácio 2010).

Anastrepha striata Schiner, 1868 infesting *P. torta* is the first report of the association between this fly species with fruits of Sapotaceae. *Anastrepha turpiniae* Stone, 1942 was obtained in the trap installed in *I. laurina* and also recovered from ripe fruits of *P. guajava*. Also verified was the presence of *Anastrepha zenildae* Zucchi, 1979 associated with ripe fruit of this Myrtaceae.

Anastrepha zernyi Lima, 1934 and *Anastrepha* sp.1 were sampled in unripe fruits of *P. torta*, however they were not captured in the trap installed in this fruit plant. *Anastrepha* sp.2 was obtained in the traps installed in *I. laurina* and *P. torta*, but was not associated with any fruit plant studied.

Ceratitis capitata (Wiedemann, 1824) was associated with the traps installed in *A. muricata*, *A. carambola* and *P. guajava*, however it was obtained only from fruit of the last two plants. The Mediterranean fruit fly was recovered from unripe and ripe fruits of *A. carambola*, but in *P. guajava* it occurred only in ripe fruits.

The absence of tephritid attack in *A. muricata*, *C. sinensis* and *D. alata*, and the low infestation in *A. occidentale* may possibly be explained by the fact that these flies are not adapted to colonize some fruits, as noted by Branco *et al*. (2000). Similar results were obtained by Souza *et al*. (2008) who found no infestations in fruits of *A. muricata*, *C. sinensis* and *A. occidentale*, and by Alvarenga *et al*. (2009), Pereira *et al*. (2010) and Silva *et al*. (2011) who also did not find any fruit fly specimens in fruits of *A. muricata*.

The temporal overlap of fruit production by different plant species may permit the maintenance of pest species populations (Ronchi-Teles & Silva 2005). However, the presence of native fruit species may be an alternative for the natural control of tephritids, since larvae of the fruit fly species that infest their fruits are reservoirs of *Anastrepha* parasitoids (López *et al*. 1999; Carvalho *et al*. 2010).

Fruit flies emerging from fruits infested with larvae occurred during the majority of the experimental period, possibly due to alternating hosts and the overlapping phenology of the fruit plant species sampled. *Anastrepha obliqua*, *A. sororcula*, *A. striata* and *C. capitata* were common throughout the study period while the other species occurred during isolated months. The population peaks of these four fly species were directly associated with the period of highest fruit production (Figs. 1 and 2). According to Ronchi-Teles & Silva (2005) the availability of the host is important for population fluctuation and abiotic factors only have little influence on these flies.

Parasitism of larvae of Tephritidae by Braconidae observed in this study was found in the same region by Nicácio *et al*. (2011) and is common in Brazil (Silva *et al*. 2007a; Souza-Filho *et al*. 2007; Leal *et al*. 2009; Ronchi-Teles *et al*. 2011). *Doryctobracon areolatus* is considered an important native species, mainly parasitizing species of *Anastrepha* in neotropical countries (Uchôa-Fernandes *et al*. 2003a; Uchôa 2012). Due to the frequency, abundance and capacity to parasitize fruit fly larvae in native and exotic fruits, this parasitoid species shows promise for integration in biological control programs of fruit flies in agroecosystems (Nunes *et al* 2011; Uchôa 2012). The low abundance of *U. anastrephae* and *Opius bellus* is common in other studies conducted in Brazil (Uchôa-Fernandes *et al*. 2003a; Lima Junior *et al*. 2007; Costa *et al*. 2009).

The dominance of *D. areolatus* is possibly related to the length of the ovipositor which permits reaching larvae in various hosts. Parasitoids with long ovipositors parasitize larvae in large and small fruit, but those with short ovipositor are limited to parasitism of larvae in small fruits (López *et al*. 1999; Sivinski *et al*. 1997, 2001; Ovruski *et al*. 2008). The higher parasitism incidence of fly larvae in ripe fruit implies possible susceptibility of these larvae during this period, since in this stage the fruits probably release a larger amount of volatiles and their pulp is softer, facilitating parasitism (Guimarães & Zucchi 2004; Silva *et al*. 2007b).

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