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Fruit flies in the Mato Grosso state, Brazil: Increasing knowledge about diversity, host plants and parasitoids

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ABSTRACT: Studies on fruit fly species are incipient in the Mato Grosso state. To obtain data on fruit flies, their host plants and parasitoids in this Brazilian state, samplings were carried out in 11 municipalities, in two periods (October to November 2018 and February to October 2019). The collections were carried out in traps and in fruits from several commercial sites. Nine species of *Anastrepha* were collected, in addition to *Ceratitis capitata* (Wiedemann, 1824) and three species of parasitoids. *Anastrepha bahiensis* Lima, 1937, *A. undosa* Stone, 1942 and the parasitoid *Opius bellus* Gahan, 1930 are being recorded for the first time in the Mato Grosso state. Additionally, new host plant records are presented for 11 fruit fly species. This is the second survey of fruit flies carried out in a large area of the Mato Grosso state.

Key words: *Anastrepha*; Braconidae; *Ceratitis capitata*; Diptera; Tephritidae

Moscas-das-frutas no Mato Grosso, Brasil: Ampliando o conhecimento sobre a diversidade, plantas hospedeiras e parasitoides

RESUMO: Os estudos sobre as espécies de moscas-das-frutas são incipientes no Estado do Mato Grosso. Com o objetivo de obter dados sobre as moscas-das-frutas, suas plantas hospedeiras e parasitoides no Estado do Mato Grosso, foram realizadas amostragens em 11 municípios, em dois períodos (outubro a novembro de 2018 e fevereiro a outubro de 2019). As coletas foram realizadas em armadilhas e em frutos de vários sítios comerciais. Foram coletadas nove espécies de *Anastrepha*, além de *Ceratitis capitata* (Wiedemann, 1824) e três espécies de parasitoides. *Anastrepha bahiensis* Lima, 1937, *A. undosa* Stone, 1942 e o parasitoide *Opius bellus* Gahan, 1930 estão sendo registrados pela primeira vez no Estado do Mato Grosso. Adicionalmente, novos registros de plantas hospedeiras são apresentadas para 11 espécies de moscas-das-frutas. Este é o segundo levantamento de moscas-das-frutas realizado em grande extensão no Estado do Mato Grosso.

Palavras-chave: *Anastrepha*; Braconidae; *Ceratitis capitata*; Diptera; Tephritidae

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Introduction

The fruit industry is an important activity of the Brazilian agribusiness and demands fresh fruit production. Brazil is the third largest producer of fruits in the world (Kist et al., 2019; Carvalho et al., 2020). The fruit production has significant economic contribution for various regions of Brazil by requiring local intensive and qualified labor generating income for the people and state.

The Mato Grosso state contributed with only 1% of fruits marketed in state in 2015, consequently, fruit sales came from other states. It is also worth noting that 30% of the local market is supplied with fruits produced in the state primarily by family farming (Damiani et al., 2017). This production system is usually conducted under low technological inputs resulting in large losses by pest.

Fruit flies (Diptera: Tephritidae) are among the most economically important pests of fruit industry worldwide (Araujo et al., 2018; Maktura et al., 2021). The economically important fruit fly species in Brazil belong to the genera *Anastrepha* (six species), *Bactrocera* (one species), and *Ceratitis* (one species) (Zucchi, 2000). Furthermore, some species have become pests in regions far from their native range, causing serious barriers for fresh fruit production and commercialization. Few insect species have a greater impact on international marketing and world trade in agricultural products than tephritid fruit flies (Radonjić et al., 2019).

Although Brazil is a large, megadiverse country, with significant biological diversity, scientific knowledge about the importance of insects in the ecosystem is neglected. Most of the knowledge is related to agricultural production, especially in the Atlantic Rain Forest or in the Cerrado biomes (Noriega et al., 2018; Ramos et al., 2020; Sousa et al., 2021). Therefore, knowledge of the tephritid species, their geographic distribution and host plants in Mato Grosso state is extremely important, not only in producing areas, but also for areas with potential for fruit production and in the surroundings of orchards too. Thus, the objective of this work was to determine the species richness of fruit flies, their respective host plants, and associated parasitoids in the Mato Grosso state, since this information is crucial for applied studies.

Materials and Methods

The present study was carried out in 11 municipalities in the Mato Grosso state, in two periods: (1) from October and November 2018 in the municipalities of Guarantã do Norte, Matupá, Peixoto de Azevedo, Sinop, and Terra Nova do Norte, and (2) from February to October 2019 in the municipalities of Acorizal, Alta Floresta, Lucas do Rio Verde, Nossa Senhora do Livramento, Poconé, Rosário Oeste, Sinop, and Sorriso (Table 1).

In the municipalities of Nossa Senhora do Livramento (15°46'27.7" S, 56°21'2.5" W) and Rosário Oeste (14°58'28.4" S, 56°22'32.6" W), only McPhail traps were used, containing Ceratrap® as a food attractant. In other municipalities, fruit samples were taken according to Silva et al. (2019). Thus, samples of fruits, potentially infested by fruit flies, were

Table 1. Species of fruit flies (Tephritidae) and their host plants in the Mato Grosso state. October - November 2018 and February to October 2019.

Species	Host plants*	Families	Fruits (n)	Mass (g)	Flies (n)	Municipalities (coordinates)
Anastrepha bahiensis	*Mangifera indica* L.	Anacardiaceae	5	576	3	Terra Nova do Norte (10°32'25.6"S - 55°05'59.1"W)
Anastrepha distincta	*Averrhoa carambola* L.	Oxalidaceae	-	-	1	Acorizal (15°08'40.8"S - 56°20'04.4"W)
	Inga edulis Martius	Fabaceae	-	-	12	Lucas do Rio Verde (13°04'28.1"S - 55°53'59.5"W)
Anastrepha fraterculus	*Averrhoa carambola* L.**	Oxalidaceae	-	-	3	Acorizal (15°08'40.8"S - 56°20'04.4"W)
			18	779	20	Guarantã do Norte (9°57'44.0"S - 54°53'24.8"W)
	Byrsonima crassifolia (L.) Kunth	Malpighiaceae	-	-	10	Poconé (16°30'59.9"S - 56°22'45.4"W)
	Eugenia uniflora L.	Myrtaceae	41	50,4	4	Sinop (11°51'32.5"S - 55°27'19.5"W)
	Eugenia pyriformis Cambess.	Myrtaceae	38	123	3	Sinop (11°51'32.5"S - 55°27'19.5"W)
	Mangifera indica L.	Anacardiaceae	-	1.432	28	Sinop (11°48'09.0"S - 55°27'52.1"W)
			5	576	1	Terra Nova do Norte (10°32'25.6"S - 55°05'59.1"W)
	Plinia cauliflora (Martius) Kausel	Myrtaceae	144	757	7	Terra Nova do Norte (10°32'20.6"S - 55°06'31.6"W)
	Psidium guajava L.	Myrtaceae	18	779	7	Guarantã do Norte (9°57'44.0"S - 54°53'24.8"W)
			40	2.045	4	Matupá (10°09'33.4"S - 54°55'49.6"W)
	Spondias mombin L.	Anacardiaceae	-	-	2	Poconé (16°30'59.9"S - 56°22'45.4"W)
	Spondias purpurea L.**	Anacardiaceae	66	848	7	Peixoto de Azevedo (10°14'22.8"S - 54°58'48.9"W)
Anastrepha leptozona	*Pouteria caimito* (Ruiz & Pav.) Radlk.	Sapotaceae	-	-	1	Sinop (11°48'05.3"S - 55°27'51.6"W)
Anastrepha obliqua	*Averrhoa carambola* L.**	Oxalidaceae	20	807	3	Terra Nova do Norte (10°32'25.6"S - 55°05'59.1"W)
	Eugenia uniflora L.	Myrtaceae	-	-	3	Lucas do Rio Verde (13°05'19.5"S - 55°53'42.6"W)
			41	50	4	Sinop (11°51'32.5"S - 55°27'19.5"W)
			14	-	4	Sorriso (12°25'33.5"S - 55°34'41.0"W)
	Plinia cauliflora (Martius) Kausel	Myrtaceae	144	757	3	Terra Nova do Norte (10°32'20.6"S - 55°06'31.6"W)
	Psidium guajava L.	Myrtaceae	18	889	22	Guarantã do Norte (9°57'44.0"S - 54°53'24.8"W)
			40	2.045	11	Matupá (10°09'33.4"S - 54°55'49.6"W)
			23	710	3	Terra Nova do Norte (10°32'35.6"S - 55°05'18.8"W)
	Spondias mombin L.	Anacardiaceae	-	-	1	Poconé (6°30'59.9"S - 56°22'45.4"W)
	Spondias purpurea L.**	Anacardiaceae	-	-	12	Lucas do Rio Verde (13°07'04.1"S - 55°53'58.3"W)
			66	848	22	Peixoto de Azevedo (10°14'22.8"S - 54°58'48.9"W)
Anastrepha pickeli	*Manihot esculenta* Crantz	Euphorbiaceae	-	-	4	Sinop (11°51'11.2"S - 55°27'22.4"W)

Continued on the next page

Continuation of Table 1

Species	Host plants*	Families	Fruits (n)	Mass (g)	Flies (n)	Municipalities (coordinates)
Anastrepha sororcula	*Eugenia uniflora* L.**	Myrtaceae	20	682	4	Guarantã do Norte (9°57'33.2"S - 54°52'42.0"W)
			-	-	4	Lucas do Rio Verde (13°05'19.5"S - 55°53'42.6"W)
			14	-	4	Sorriso (12°25'33.5"S - 55°34'41.0"W)
	Plinia cauliflora (Martius) Kausel**	Myrtaceae	144	757	5	Terra Nova do Norte (10°32'20.6"S - 55°06'31.6"W)
	Psidium guajava L.	Myrtaceae	40	2.045	14	Matupá (10°09'33.4"S - 54°55'49.6"W)
			20	682	1	Guarantã do Norte (9°57'44.0"S - 54°53'24.8"W)
			41	50	7	Sinop (11°51'32.5"S - 55°27'19.5"W)
			23	710	5	Terra Nova do Norte (10°32'35.6"S - 55°05'18.8"W)
	Psidium guineense Sw.	Myrtaceae	-	-	1	Poconé (16°30'59.9"S - 56°22'45.4"W)
	Spondias purpurea L.	Anacardiaceae	192	281	4	Sinop (11°51'32.5"S - 55°27'19.5"W)
Anastrepha striata	*Eugenia uniflora* L.	Myrtaceae	-	-	14	Lucas do Rio Verde (13°05'19.5"S - 55°53'42.6"W)
	Mangifera indica L.	Anacardiaceae	-	1.432	1	Sinop (11°48'09.0"S - 55°27'52.1"W)
	Psidium guajava L.**	Myrtaceae	11	-	6	Alta Floresta (9°44'00.2"S - 56°05'01.8"W)
			20	682	14	Guarantã do Norte (9°56'34.7"S - 54°54'04.1"W)
			-	-	58	Lucas do Rio Verde (13°06'59.6"S - 55°55'03.7"W)
			40	2.045	20	Matupá (10°09'33.4"S - 54°55'49.6"W)
			23	710	8	Terra Nova do Norte (10°32'35.6"S - 55°05'18.8"W)
Anastrepha turpiniae	*Mangifera indica* L.	Anacardiaceae	12	-	1	Sinop (11°51'24.8"S - 55°34'18.2"W)
Ceratitis capitata	*Averrhoa carambola* L.**	Oxalidaceae	-	-	14	Lucas do Rio Verde (13°06'59.6"S - 55°55'03.7"W)
	Chrysophyllum cainito L.	Sapotaceae	-	-	6	Lucas do Rio Verde (13°03'45.2"S - 55°54'24.4"W)
	Eugenia pyriformis Cambess.	Myrtaceae	11	57,9	4	Sinop (11°51'35.9"S 55°27'19.0"W)
	Malpighia emarginata DC.**	Malpighiaceae	-	-	4	Lucas do Rio Verde (13°06'59.6"S - 55°55'03.7"W)
			14	85	32	Matupá (10°09'33.4"S - 54°55'49.6"W0
	Pouteria caimito (Ruiz & Pav.) Radlk.	Sapotaceae	-	-	5	Sinop (11°50'33.9"S - 55°30'27.1"W)
	Psidium guajava L.**	Myrtaceae	40	2.045	4	Matupá (10°09'33.4"S - 54°55'49.6"W)

* According to WFO (2021).
** Previously recorded by Souza et al. (2017) and Silva et al. (2019).

collected in orchards of small rural properties. The fruits were collected from the trees and the ground, stored in kraft paper bags and taken to the Entomology Laboratory of the Universidade Federal de Mato Grosso (UFMT), Campus Sinop. The geographic coordinates of the collection points were registered by GPS (Global Positioning System). In the laboratory, the fruits of each sample, belonging to the same species, were placed together in plastic containers with lids covered with fabric microscreens, to allow air circulation and to prevent the escape of the emerged insects. In the bottom of the containers, 3 to 4 cm of expanded vermiculite were placed for the larvae to pupate. The containers were stored on shelves and at room temperature of 22 a 25 °C for about 20 to 30 days, a period sufficient for the emergence of flies or parasitoids. The insects were killed (frozen for 10 min) and placed in microtubes containing 70% ethanol, properly labeled, for later identification. The specimen vouchers are kept in 70% ethanol and deposited in the collection of Embrapa Amapá. The fruit flies were identified by MSMS. *Anastrepha* species identifications were based exclusively on females (wing pattern, thoracic characters and aculeus tip) and *Ceratitis capitata* (Wiedemann) was recognized by external characters (wing pattern and thorax). The fruit fly parasitoids were identified according to Marinho et al. (2018). The plant species sampled were identified by comparison with exsiccates from the Center-North-Mato-Grossense (CNMT) Herbarium.

Results

Eleven species of fruit flies were collected, namely, *Anastrepha bahiensis* Lima, 1937; *A. distincta* Greene, 1934; *A. fraterculus* (Wiedemann, 1830); *A. leptozona* Hendel, 1914; *A. obliqua* (Macquart, 1835); *A. pickeli* Lima, 1934; *A. sororcula* Zucchi, 1979; *A. striata* Schiner, 1868; *A. turpiniae* Stone, 1942; *A. undosa* Stone, 1942, and *C. capitata*.

Specimens of *A. bahiensis*, *A. fraterculus*, *A. leptozona*, *A. obliqua*, *A. sororcula*, *A. striata*, and *C. capitata* were collected from fruits in the municipalities of Guarantã do Norte, Matupá, Peixoto de Azevedo, Sinop and Terra Nova do Norte, in 2018 (Table 1). Specimens of *A. distincta*, *A. fraterculus*, *A. obliqua*, *A. pickeli*, *A. sororcula*, *A. striata*, *A. turpiniae*, and *C. capitata* were collected in the municipalities of Alta Floresta, Lucas do Rio Verde, Nossa Senhora do Livramento, Poconé, Rosário Oeste, Sinop and Sorriso, in 2019 (Table 1). Only *A. undosa* was captured exclusively in McPhail traps in Rosário Oeste. *Anastrepha obliqua* was captured in traps in Nossa Senhora do Livramento, but it was also sampled from fruits in several municipalities (Table 1).

Fifteen host plant species, belonging to six families, were recorded. Guava (*Psidium guajava* L.) was the host with the most species of fruit flies associated (5 species), followed by mango (*Mangifera indica* L.), carambola (*Averrhoa carambola* L.), and pitanga (*Eugenia uniflora* L.) (4 species each). Fruit flies with more host plants associated were *A. fraterculus* (9 fruit species), *A. obliqua* (6 fruit species), *A. sororcula*, and *C. capitata* (6 fruit species each) (Table 1).

Opius bellus Gahan, 1930 (Hymenoptera: Braconidae) is being recorded for the first time in the Mato Grosso state. Two specimens were obtained from fruit fly larvae/pupae infesting pitanga (*E. uniflora*) from the municipality of Guarantã do Norte, associated to *A. sororcula*, and in fruits of siriguela (*Spondias purpurea* L.), from Sinop, but it is not

Table 2. Parasitoid braconids (Hymenoptera) of fruit flies (Tephritidae) from the Mato Grosso state.

Parasitoids	Fruit flies	Host plants	Municipalities (coordinates)
Doryctobracon areolatus (Szépligeti, 1911)	-	*Averrhoa carambola* L.	Guarantã do Norte[3] (9°57'44.0"S 54°53'24.8"W)
			Terra Nova do Norte[3] (10°32'25.6"S 55°05'59.1"W)
	-	*Psidium guajava* L.[2]	Guarantã do Norte[3] (9°57'44.0"S 54°53'24.8"W)
			Lucas do Rio Verde[3] (13°03'46.6"S 55°54'21.5"W)
			Matupá[3] (10°09'33.4"S 54°55'49.6"W)
			Terra Nova do Norte[3] (10°32'35.6"S 55°05'18.8"W)
	-	*Annona crassiflora* Martius[2]	Guarantã do Norte[3] (9°56'32.3"S 54°53'51.9"W)
	-	*Spondias purpurea* L.[2]	Peixoto de Azevedo[3](10°14'22.8"S 54°58'48.9"W)
			Sinop[3] (11°51'32.5"S 55°27'19.5"W)
	-	*Eugenia uniflora* L.	Lucas do Rio Verde[3] (13°05'19.5"S 55°53'42.6"W)
			Sorriso[3] (12°25'33.5"S 55°34'41.0"W)
Opius bellus Gahan, 1930[1]	*A. sororcula*	*Spondias purpurea* L.	Guarantã do Norte (9°57'33.2"S 54°52'42.0"W)
	-	*Eugenia uniflora* L.	Sinop (11°51'32.5"S 55°27'19.5"W)
Utetes anastrephae (Viereck, 1913)	-	*Spondias mombin* L.	Peixoto de Azevedo[3] (10°14'22.8"S 54°58'48.9"W)
			Poconé[3] (16°30'25.8"S 56°24'43.2"W)
	-	*Eugenia uniflora* L.	Guarantã do Norte[3] (10°14'22.8"S 54°58'48.9"W)

New records: [1] parasitoid; [2] associated plant; [3] occurrence.

possible associate with the fruit fly species. In addition, the parasitoids *Doryctobracon areolatus* (Szépligeti, 1911) and *Utetes anastrephae* (Viereck, 1913) were also recorded in new hosts and new occurrence locations in the Mato Grosso state (Table 2).

Discussion

About two decades ago, only eight species of *Anastrepha*, from occasional collections were reported for the Mato Grosso state (Uchôa & Zucchi 2000). In the following years, another 13 species of *Anastrepha* and *C. capitata* were recorded (Pontes, 2006) and *A. matogrossensis* Norrbom & Uchôa (2011) was described. In a survey in the municipality of Santo Antônio de Leverger, 10 species of fruit flies were collected in plastic bottle traps, with three new records for the state (*A. amita* Zucchi, 1979; *A. fractura* Stone, 1942, and *A. mucronota* Stone, 1942) (Silva et al., 2017). The two most recent records in Mato Grosso state were *A. montei* Lima, 1934 and *A. tumida* Stone, 1942, collected in Colíder (Nobre & Uchoa, 2018).

In this study, two new records of *Anastrepha* for Mato Grosso state were obtained (*A. bahiensis* and *A. undosa*). Twenty-four new host plant records are being recorded for 10 *Anastrepha* species, namely, *A. bahiensis* (1 host), *A. distincta* (2 hosts), *A. fraterculus* (7 hosts), *A. leptozona* (1 host), *A. obliqua* (4 hosts), *A. pickeli* (1 host), *A. sororcula* (3 hosts), *A. striata* (2 hosts), *A. turpiniae* (1 host), and *C. capitata* (2 hosts) (Table 1). Sixteen plant species, distributed in 7 families are registered in this publication as host plants.

The plant hosts, sampled in this study, are widely distributed, since they are used in human food and are easily adapted to different types of soil and climate. Although their fruiting is restricted to a certain time of year, they serve as breeding sites for many fruit fly species. *Anastrepha obliqua* was associated with species of the Myrtaceae family, but it can also attack Anacardiaceae species (Almeida et al., 2019; Alves et al., 2020; Zucchi & Moraes, 2021). Furthermore, our results are in agreement with those obtained by Araújo et al. (2021), who report *A. sororcula* as one of the most frequent species in domestic orchards in Areia, Paraíba.

Although *C. capitata* was recorded in Brazil for over 120 years (Zucchi, 2015), it was found in Mato Grosso state about 15 years ago (Pontes, 2006). Additionally, the Mediterranean fruit fly attacks 115 host plants in Brazil, but only eight are recorded in the Mato Grosso state (Zucchi & Moraes, 2022). This information shows how the fruit fly surveys have been neglected in the state. We collected *C. capitata* from five hosts, of which two (*Chrysophyllum cainito* and *Pouteria caimito*) are new host plant records of this species in Brazil (Table 1). Therefore, our findings increase for ten the number of host plants of *C. capitata* in the Mato Grosso state, and contributes to the knowledge of the dispersion of this species in the Brazilian Amazon. The occurrence of *C. capitata* represents a concern for fruit growing, because it is an invasive species, that it is extending its distribution in Brazil (Zucchi, 2015), and causes significant losses in fruit production (Louzeiro et al., 2021).

Surveys on fruit fly parasitoids are recent in the Mato Grosso state, consequently these parasitoids are poorly known in the state. Out of 12 parasitoids recorded in Brazil (Marinho et al., 2018) only three were recorded herein, and only one of them, *Opius bellus*, was associated with a species of *Anastrepha* (first record). Furthermore, our records of *D. areolatus* and *U. anastrephae* in Mato Grosso state extend the distribution of these parasitoids in Brazil (Table 2). The first parasitoid collected in the Mato Grosso state was *D. areolatus*, in Sinop (Souza et al., 2017). Previously, *D. areolatus*, *U. anastrephae*, and *Asobara anastrephae* (Muesebeck 1958) were collected in Nova Guarita (Silva et al., 2019). *Doryctobracon areolatus* is the most widely distributed species, and with more association with fruit fly host plants (Marinho et al., 2018; Zucchi & Moraes, 2022).

Based on previous records (see Zucchi & Moraes, 2022) and on new data reported here, 26 *Anastrepha* species, 19 host species and four fruit fly parasitoid braconids are registered in Mato Grosso state, besides of two new host records for *C.*

capitata. These data include information on biodiversity, host association, geographical distribution and parasitoids, which are important to establish management strategies. In addition, data on fruit fly host plants are useful for the establishment of conservative biological control. Therefore, the continuous development of research involving the bioecology of fruit flies should be prioritized in the region, to contribute to the sustainability and commercialization of fresh fruits produced in the Mato Grosso state.

Conclusions

This work expands the knowledge about fruit flies, their host plants and parasitoids in the Mato Grosso state. The data were originated from 15 native and cultivated fruit species sampled, ten fruit fly species and four braconid parasitoids were collected. Among these data, *Anastrepha bahiensis* and *A. undosa*, as well as the parasitoid *Opius bellus*, associated with *A. sororcula*, were recorded for the first time in the Mato Grosso state. *Chrysophyllum cainito* and *Pouteria caimito* are reported for the first time as a host of *C. capitata* in Brazil, increasing to ten the number of hosts for this species in the Mato Grosso state.

This information on diversity, hosts and natural enemies has direct implications for the development of pest management strategies. Also, information such as that generated in this study is essential, given the interest of several research groups in analyzing the diversity and phylogenetics of *Anastrepha* species.

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Compliance with Ethical Standards

Author contributions: Conceptualization: MRB, RA; Data curation: MRB, RA; Formal analysis: MRB, RA, RAZ; Investigation: MRB, MSMS, RA, RAZ; Project administration: MRB; Supervision: MRB; Visualization: MRB, RA; Writing - original draft: MRB, MSMS, RA, RAZ; Writing - review & editing: MRB, RA, RAZ.

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