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Species of *Anastrepha* (Diptera: Tephritidae), their host plants, and parasitoids in small fruit production areas in the state of Amapá, Brazil

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Abstract

Fruit flies and associated parasitoids were determined in native and introduced fruit species in the state of Amapá, Brazil. Fruits were collected every 30 d, from Jan to Dec 2012, on 3 small farms in the municipalities of Mazagão, Porto Grande, and Santana. We collected 412 samples (78 species of plants belonging to 32 families and consisting of 4,554 fruits weighing 323.4 kg) and obtained 5,252 *Anastrepha* (Diptera: Tephritidae) puparia from 107 infested samples (20 plant species from 13 botanical families). We report here the occurrence of 11 species of *Anastrepha* and 5 species of parasitoids (4 Braconidae and 1 Figitidae species; both families in the order Hymenoptera). New hosts for *Anastrepha distincta* Greene, *Anastrepha leptozona* Hendel, *Anastrepha obliqua* (Macquart), and *Anastrepha serpentina* (Wiedemann) were documented in Brazil.

Key Words: fruit fly; infestation; host fruit; Amazon

Resumo

Moscas-das-frutas e parasitoides associados foram reportados em espécies vegetais frutíferas nativas e introduzidas no estado do Amapá, Brasil. Frutos foram coletados a cada 30 dias, de janeiro a dezembro de 2012, em 3 pequenas propriedades agrícolas nos municípios de Mazagão, Porto Grande e Santana. Nós coletamos 412 amostras (78 espécies de plantas pertencentes a 32 famílias, consistindo de 4.554 frutos, pesando 323,4 kg) e obtivemos 5.252 pupários de *Anastrepha*, a partir de 107 amostras infestadas (20 espécies vegetais de 13 famílias botânicas). Reportamos a ocorrência de 11 espécies de *Anastrepha* e 5 de parasitoides (4 Braconidae e 1 Figitidae; ambos Hymenoptera). Novos hospedeiros para *Anastrepha distincta* Greene, *Anastrepha leptozona* Hendel, *Anastrepha obliqua* (Macquart) e *Anastrepha serpentina* (Wiedemann) foram documentados para o Brasil.

Palavras Chave: moscas-das-frutas; infestação; fruto hospedeiro; Amazônia

Fruit flies (Diptera: Tephritidae) are among the principal pests in agriculture (Malavasi 2009). In addition to the direct damage caused by the development of larvae inside the fruits, there are signficant monetary losses caused by quarantine restrictions for certain species of fresh fruit destined for export (Carvalho et al. 2000). Among the Tephritidae, the genus *Anastrepha* Schiner, endemic to the Neotropical region, has greatest economic impact in the Americas. *Anastrepha* is quite diverse, with 235 species described, and is widely distributed in the American tropical and subtropical regions (Aluja 1994; Uramoto et al. 2008; Uchôa & Nicácio 2010). In Brazil, 120 species have already been reported (Zucchi 2008).

In the Brazilian Amazon, 76 *Anastrepha* species are known (Adaime et al. 2016). Of these, 5 are considered of economic importance: *Anastrepha fraterculus* (Wiedemann), *Anastrepha obliqua* (Macquart), *Anastrepha pseudoparallela* (Loew), *Anastrepha striata* Schiner, and *Anastrepha zenildae* Zucchi (Uramoto & Zucchi 2009; Dutra et al. 2013; Adaime et al. 2016). In Amapá, 37 species of *Anastrepha* are already documented, making this state the second one in species richness in the Amazon region (Zucchi 2008).

Despite the economic importance of Tephritidae, the association of fruit fly species with host plants has not been established for most of the known species in the Brazilian Amazon (Zucchi et al. 2011a). The identification of the host fruits is essential for the establishment of an adequate and efficient management program for the pest species (Jesus-Barros et al. 2012). From fruit collections, it is possible to determine the rates of fruit infestation by tephritids and the parasitism rates of the tephritids by parasitoids (Silva et al. 2011a). These relationships can also provide information on the life history of fruit fly species because the host plant, together with temperature, humidity and natural enemies, can affect larval development, adult fecundity, and survival rate. In addition, the understanding of these relationships provides information on the structure of the fruit fly community in the Brazilian Amazon, because the host plant may have a direct effect on the distribution and abundance of *Anastrepha* species. It is worth not-

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ing that tephritids show different degrees of specialization on species of plants native to the American continent, ranging from monophagy to polyphagy (Duyck et al. 2004; Aluja & Mangan 2008; Malavasi 2009; Hafsi et al. 2016).

Fruit production areas in the Brazilian Amazon, especially in the state of Amapá, are mostly characterized by the use of agroforestry systems and urban and rural backyards usually surrounded by native vegetation. This design can favor infestation by fruit flies because there are about 200 fruit species in the Brazilian Amazon, of which half are native and have the potential to host tephritid species. In addition, the availability of cultivated fruits, together with the high diversity of native plant species that fruit throughout the year, may allow the succession of hosts and the maintenance of fruit fly populations (Silva & Ronchi-Teles 2000).

Host availability is one of the main factors affecting the population dynamics of fruit flies. Jesus-Barros et al. (2012), in a study carried out in the state of Amapá, observed that the highest rates of infestation by *Anastrepha* were recorded in native fruits of the Amazon region. Lemos et al. (2015), in a study carried out in the southeast region of Brazil, found that the population dynamics of *Anastrepha* in guava orchards was influenced by the availability of alternative hosts in the areas adjacent to the orchard.

The action of natural enemies is another biotic factor, as well as host availability and phenology, which has a strong influence on the population regulation of tephritid species (Leal et al. 2009; Aluja et al. 2012). In the Neotropical region, the braconid parasitoids are among the principal mortality factors of *Anastrepha* (Carvalho et al. 2010). *Doryctobracon areolatus* (Szépligeti) (Hymenoptera: Braconidae) has been shown to be the most abundant and widely distributed parasitoid in Brazil (Jesus-Barros et al. 2012). Nonetheless, natural parasitism in the various fruit producing regions in Brazil is variable because it is influenced by the host plant species, by the host fly, and by the place and time of collection (Ovruski et al. 2000; Bittencourt et al. 2012) .

The aim of this research was to identify species of *Anastrepha* and their host plants and associated parasitoids in fruit production areas of 3 municipalities in the state of Amapá in the Brazilian Amazon.

Materials and Methods

STUDY SITE

We conducted this study on 3 farms located in the municipalities of Mazagão, Porto Grande, and Santana, state of Amapá, Brazil. All 3 properties contained commercial orchards with adjoining areas of native forest.

The area in Mazagão (0.1°S, 51.25°W) exhibits native floodplain forest vegetation, which undergoes daily flooding due to tides. Common species include *Platymiscium duckei* Huber (Fabaceae), *Virola surinamensis* (Rol.) Warb. (Myristicaceae), *Calycophyllum spruceanum* (Benth.) Hook. f. ex K. Schum. (Rubiaceae), and *Carapa guianensis* Aubl. (Meliaceae). The commercial orchard area occupies an area of approximately 10 ha, with cultivated fruit trees including Tahiti lime (*Citrus aurantifolia* Swingle 'Tahiti'; Rutaceae), passionfruit (*Passiflora edulis* Sims; Passifloraceae), and soursop (*Annona muricata* L.; Annonaceae) grown to make fruit concentrate or to be sold fresh.

The area in Porto Grande (0.6°N, 1.45°W) exhibits dense forest vegetation with numerous tree species including *Protium* species (Burseraceae), *Caryocar villosum* (Aubl.) Pers. (Caryocaraceae), and *Dipteryx odorata* (Aubl.) Willd. (Fabaceae). The property covers approximatly 100 ha, of which 30% is used for the cultivation of fruit trees, mainly hog plum (*Spondias mombin* L.; Anacardiaceae), araza (*Eugenia stipitata* McVaugh; Myrtaceae), and soursop (*A. muricata*).

The area in Santana (0.03°S, 51.21°W) exhibits secondary forest vegetation with *Eschweilera tenuifolia* Miers (Lecythidaceae), *Ficus pertusa* L. f. (Moraceae), and *Pourouma guianensis* Aubl. (Urticaceae) as predominant species. The commercial orchard is approximately 20 ha, and the main species are acerola (*Malpighia emarginata* DC; Malpighiaceae), guava (*Psidium guajava* L.; Myrtaceae), and passionfruit (*P. edulis*).

As classified by Köppen, the climate type at the study sites is Am, characterized as hot and humid with a short dry season in the spring. Rainfall is distributed between 2 well-defined periods: a rainy season (Jan–Jul), which receives about 80% of all annual rainfall in the area, and a dry season (Aug–Dec). Temperatures are high throughout the year, with an annual average of 25 to 27 °C (low of 22 °C and high of 34 °C) (IBGE 2010).

EXPERIMENTAL PROCEDURES

Samples were obtained from fruit crops and adjacent areas of native vegetation. Once a month from Jan to Dec 2012, fruits were collected from various plant species either directly from the plant or by retrieving recently fallen fruit. Samples were transported in stackable plastic crates to the Entomology Laboratory at Embrapa Amapá, where the fruits were weighed on a digital scale. For preparation of the samples, the fruits were processed and individualized as per the sample size criterion established by Silva et al. (2011a): a) 15 units, for small fruits; b) 10 units, for medium-sized fruits; and c) 3 units, for large or elongated fruits. In each sample, each individual fruit was considered as 1 sub-sample.

The collected fruits were placed either individually in tubular, transparent plastic vials (8 × 6 cm DH) with vented lids lined with organza or, in the case of large or elongated fruits, on rectangular plastic trays (33 × 18 × 6 cm LWH) also covered with organza held in place by rubber bands. Both types of containers included a thin layer of sterilized sand as a substrate for pupation.

Every 3 d, the sand was examined, and tephritid puparia were removed with spatulas. The puparia were transferred to transparent plastic vials (8 cm diameter) with vented lids covered with organza and containing a thin layer of moistened vermiculite. The adult insects that emerged were killed, transferred to microcentrifuge tubes containing 70% ethanol, and labeled for subsequent identification.

The insects obtained were identified according to Zucchi et al. (2011b) and Marinho et al. (2011). Wild plant species were identified with identification keys and by comparison with specimens available at the Herbário Amapaense, the herbarium at the Amapá State Institute for Scientific and Technological Research (Macapá, Amapá, Brazil).

The following infestation rates were calculated: 1) percentage of fruits infested = (number of fruits infested ÷ number of fruits collected) × 100; 2) number of puparia per fruit = number of puparia obtained ÷ number of infested fruits in the sample.

Results

During the sampling period, 412 fruit samples (4,554 fruits; 323.4 kg) representing 78 plant species (51 native and 27 introduced) were obtained from 32 botanical families (Table 1). Infestation was observed in 107 (26.0%) collected samples, representing 20 plant species in 13 botanical families (Tables 1 and 2). In total, 5,252 puparia were obtained, from which emerged specimens of 11 species of *Anastrepha* and 5 species of parasitoids (4 Braconidae and 1 Figitidae species; both Hymenoptera). The species of *Anastrepha* obtained were: *Anastrepha antunesi* Lima, *Anastrepha coronilli* Carrejo & González, *Anastrepha*

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Table 1. Number of fruit samples and individual fruits collected, and number infested by *Anastrepha* species, from 3 municipalities in the state of Amapá, Brazil (Jan–Dec 2012).

Scientific name	Common name [Portuguese]	Family	Origin N / I	Mazagão				Porto Grande				Santana			
				CS	CF	IS	IF	CS	CF	IS	IF	CS	CF	IS	IF
Alibertia edulis (Rich.) A. Rich.	Puruí	Rubiaceae	N	0	0	0	0	2	30	0	0	0	0	0	0
Anacardium occidentale L.	Caju	Anacardiaceae	I	1	10	0	0	0	0	0	0	2	20	0	0
Annona mucosa Jacq.	Biribá	Annonaceae	N	0	0	0	0	3	9	0	0	0	0	0	0
Annona muricata L.	Graviola	Annonaceae	I	1	3	0	0	4	12	0	0	2	6	1	1
Artocarpus altilis (Parkinson) Fosberg	Fruta-pão	Moraceae	I	0	0	0	0	4	12	0	0	0	0	0	0
Artocarpus heterophyllus Lam.	Jaca	Moraceae	I	0	0	0	0	2	6	0	0	3	9	0	0
Astrocaryum aculeatum G. Mey.	Tucumã	Arecaceae	N	0	0	0	0	0	0	0	0	1	15	0	0
Astrocaryum murumuru Mart.	Murumuru	Arecaceae	N	6	60	0	0	0	0	0	0	0	0	0	0
Attalea maripa (Aubl.) Mart.	Inajá	Arecaceae	N	0	0	0	0	1	15	0	0	0	0	0	0
Attalea phalerata Mart. ex Spreng.	Urucuri	Arecaceae	N	7	70	0	0	0	0	0	0	0	0	0	0
Averrhoa carambola L.	Carambola	Oxalidaceae	I	0	0	0	0	9	90	0	0	0	0	0	0
Bactris gasipaes Kunth	Pupunha	Arecaceae	I	0	0	0	0	2	30	0	0	0	0	0	0
Bactris maraja Mart.	Marajá	Arecaceae	N	1	15	0	0	0	0	0	0	0	0	0	0
Bellucia egensis (DC.) Penneys, Michelangeli, Judd, Almeda	Verde-peludo	Melastomataceae	N	0	0	0	0	3	45	0	0	4	60	0	0
Bellucia grossularioides (L.) Triana	Goiaba-de-anta	Melastomataceae	N	0	0	0	0	2	30	2	6	0	0	0	0
Byrsonima crassifolia (L.) Kunth	Muruci	Malpighiaceae	N	0	0	0	0	0	0	0	0	5	75	0	0
Calophyllum brasiliensis Cambess.	Jacareúba	Calophyllaceae	N	1	15	0	0	0	0	0	0	0	0	0	0
Capsicum chinense Jacq.	Pimentinha	Solanaceae	I	8	120	0	0	1	15	0	0	3	45	0	0
Carica papaya L.	Mamão	Caricaceae	I	1	3	0	0	5	15	0	0	6	90	0	0
Caryocar glabrum (Aubl.) Pers.	Piquiarana	Caryocaraceae	N	0	0	0	0	1	10	0	0	0	0	0	0
Cayaponia ferruginea Gomes-Klein	Fruta de cutia	Curcubitaceae	N	0	0	0	0	0	0	0	0	1	15	0	0
Cheiloclinium cognatum (Miers) A.C. Sm.	Bacupari	Celastraceae	N	2	30	1	1	0	0	0	0	3	45	1	1
Cissus amapaensis Lombardi	Uva-do-mato	Vitaceae	N	0	0	0	0	0	0	0	0	2	30	0	0
Citrus aurantifolia Swingle 'Tahiti'	Limão taiti	Rutaceae	I	9	90	0	0	0	0	0	0	3	30	0	0
Citrus aurantium L.	Laranja-da-terra	Rutaceae	I	0	0	0	0	10	100	0	0	0	0	0	0
Citrus latifolia Tanaka	Limão galego	Rutaceae	I	0	0	0	0	0	0	0	0	2	20	0	0
Citrus limonia Osbeck	Limão-cravo	Rutaceae	I	8	80	0	0	8	80	0	0	11	110	0	0
Citrus reticulata Blanco	Tangerina	Rutaceae	I	2	20	0	0	4	40	0	0	5	50	0	0
Citrus sinensis (L.) Osbeck	Laranja	Rutaceae	I	4	40	0	0	0	0	0	0	1	10	0	0
Coffea arabica L.	Café	Rubiaceae	I	0	0	0	0	0	0	0	0	3	45	0	0
Combretum laxum Jacq.	Pombeiral	Combretaceae	N	0	0	0	0	2	30	0	0	0	0	0	0
Conceveiba guianensis Aubl.	Arraieira	Euphorbiaceae	N	0	0	0	0	0	0	0	0	1	15	0	0
Cucumis anguria L.	Maxixe	Curcubitaceae	N	5	75	0	0	1	15	0	0	1	15	0	0
Cucumis sativus L.	Pepino	Curcubitaceae	I	5	15	0	0	0	0	0	0	1	3	0	0
Eschweilera tenuifolia (O. Berg) Miers [flower bud]	Matá-matá	Lecythidaceae	N	0	0	0	0	0	0	0	0	4	60	0	0
Eugenia stipitata McVaugh	Araçá-boi	Myrtaceae	N	0	0	0	0	11	110	11	102	0	0	0	0
Ficus pertusa L. f.	Apuí	Moraceae	N	2	30	0	0	2	30	0	0	1	15	0	0
Geissospermum sericeum Miers	Quinarana	Apocynaceae	N	0	0	0	0	2	20	0	0	0	0	0	0
Guarea guidonia (L.) Sleumer	Jataúba	Meliaceae	N	0	0	0	0	1	15	0	0	0	0	0	0
Gustavia augusta L.	Jenipaparana	Lecythidaceae	N	0	0	0	0	0	0	0	0	1	10	0	0
Inga edulis Mart.	Ingá-cipó	Fabaceae	N	2	6	2	6	0	0	0	0	5	15	3	15
Licania laxiflora Fritsch	Anoerá	Chrysobalanaceae	N	5	45	0	0	0	0	0	0	1	15	1	1

N = Native; I = Introduced; CS = collected samples; CF = collected fruits; IS = infested samples; IF = infested fruits.

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Table 1. (Continued) Number of fruit samples and individual fruits collected, and number infested by *Anastrepha* species, from 3 municipalities in the state of Amapá, Brazil (Jan–Dec 2012).

Scientific name	Common name [Portuguese]	Family	Origin N / I	Mazagão				Porto Grande				Santana			
				CS	CF	IS	IF	CS	CF	IS	IF	CS	CF	IS	IF
Malpighia emarginata DC	Acerola	Malpighiaceae	I	1	15	1	4	4	60	4	15	9	135	9	80
Mammea americana L.	Abricó	Clusiaceae	I	0	0	0	0	3	30	0	0	0	0	0	0
Mangifera indica L.	Manga comum	Anacardiaceae	I	2	20	0	0	1	10	0	0	2	20	0	0
Mangifera indica L. 'Tommy Atkins'	Manga cavalo	Anacardiaceae	I	0	0	0	0	7	21	0	0	0	0	0	0
Manicaria saccifera Gaertn	Bussu	Arecaceae	N	1	15	0	0	0	0	0	0	0	0	0	0
Manihot esculenta Crantz	Mandioca	Euphorbiaceae	N	0	0	0	0	1	15	1	1	1	15	0	0
Manilkara elata (Alemão ex Miq.) Monach	Maçaranduba	Sapotaceae	N	2	30	0	0	0	0	0	0	0	0	0	0
Manilkara zapota (L.) P. Royen	Sapotilha	Sapotaceae	I	0	0	0	0	12	120	6	38	0	0	0	0
Metrodorea flavida K. Krause	Laranjinha	Rutaceae	N	4	60	0	0	0	0	0	0	0	0	0	0
Oenocarpus bacaba Mart.	Bacaba	Arecaceae	N	1	15	0	0	1	15	0	0	6	90	1	1
Parinari excelsa Sabine	Isqueira	Chrysobalanaceae	N	1	15	0	0	0	0	0	0	0	0	0	0
Passiflora edulis Sims [flower bud]	Maracujá	Passifloraceae	N	5	75	0	0	0	0	0	0	3	45	0	0
Passiflora edulis Sims	Maracujá	Passifloraceae	N	8	80	0	0	0	0	0	0	2	20	0	0
Persea americana Mill.	Abacate	Lauraceae	I	0	0	0	0	4	12	0	0	4	12	1	1
Physalis angulata L.	Camapu	Solanaceae	I	1	15	0	0	0	0	0	0	0	0	0	0
Plinia cauliflora (Mart.) Kausel	Jaboticaba	Myrtaceae	I	0	0	0	0	1	15	1	6	0	0	0	0
Pourouma guianensis Aubl.	Mapatirana	Urticaceae	N	0	0	0	0	1	15	1	6	0	0	0	0
Pouteria caimito (Ruiz & Pav.) Radlk.	Abiu	Sapotaceae	N	1	10	0	0	0	0	0	0	1	10	1	2
Pouteria gardneri (Mart. & Miq.) Baehni	Aguaí-una	Sapotaceae	N	0	0	0	0	1	15	1	1	0	0	0	0
Pouteria macrophylla (Lam.) Eyma	Cutite	Sapotaceae	N	0	0	0	0	4	40	0	0	0	0	0	0
Protium heptaphyllum (Aubl.) Marchand	Breu vermelho	Burseraceae	N	1	15	0	0	0	0	0	0	0	0	0	0
Protium sp.	Breu branco	Burseraceae	N	1	15	0	0	1	15	0	0	0	0	0	0
Psidium guajava L.	Goiaba	Myrtaceae	I	4	40	4	33	0	0	0	0	12	120	12	118
Quararibea guianensis Aubl.	Inajarana	Malvaceae	N	3	45	1	2	0	0	0	0	0	0	0	0
Solanum aethiopicum L.	Jiló	Solanaceae	I	3	30	0	0	0	0	0	0	0	0	0	0
Solanum paniculatum L.	Jurubeba	Solanaceae	N	0	0	0	0	1	15	0	0	4	60	0	0
Spondias dulcis Forst.	Cajarana	Anacardiaceae	I	0	0	0	0	11	110	11	4	0	0	0	0
Spondias mombin L.	Taperebá	Anacardiaceae	N	3	45	3	24	6	90	6	77	5	75	5	43
Spondias purpurea L.	Siriguela	Anacardiaceae	I	7	105	4	48	9	135	7	99	0	0	0	0
Strychnos asperula Sprague & Sandwith	Gogó-de-guariba	Loganiaceae	N	0	0	0	0	0	0	0	0	1	15	0	0
Symphonia globulifera L. f.	Anani	Clusiaceae	N	3	45	0	0	0	0	0	0	0	0	0	0
Syzygium cumini (L.) Skeels	Jambolão	Myrtaceae	I	1	15	0	0	0	0	0	0	1	15	0	0
Syzygium jambos (L.) Alston	Jambo vermelho	Myrtaceae	I	3	30	0	0	2	20	0	0	2	20	0	0
Tapirira obtusa (Benth.) J. D. Mitch.	Fruto de pombo	Anacardiaceae	N	0	0	0	0	0	0	0	0	3	45	0	0
Theobroma cacao L.	Cacau	Malvaceae	I	1	3	0	0	4	12	0	0	0	0	0	0
Trattinnickia rhoifolia Willd.	Amesclão	Burseraceae	N	0	0	0	0	0	0	0	0	1	15	0	0
Trichilia rubra C. DC.	Cachuá	Meliaceae	N	1	15	0	0	0	0	0	0	0	0	0	0
Trymatococcus amazonicus Poepp. & Endl.	Inharé	Moraceae	N	1	15	0	0	0	0	0	0	0	0	0	0
No. species = 78		No. families = 32		129	1,495	17	126	154	1,524	51	356	129	1,535	39	296

N = Native; I = Introduced; CS = collected samples; CF = collected fruits; IS = infested samples; IF = infested fruits.

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Table 2. Species of *Anastrepha*, host plants, and associated parasitoids in 3 municípalities in the state of Amapá, Brazil (Jan–Dec 2012).

FAMILY Species[a]	Puparia (*n*)	Infestation[b] % FI	P/F	*Anastrepha* species[c] and parasitoid species[d] Mazagão[e]	Porto Grande[e]	Santana[e]
ANACARDIACEAE						
Spondias dulcis●	45	4.0	11.3	—	Ao(7♀), 5♂	—
Spondias mombin●	918	60.0	6.4	Ao(9♀), Aa(2♀), 11♂ + Ob(12), Da(7)	Ao(99♀), Aa(20♀), Af(1♀), Ast(1♀), 96♂ + Ob(60), Da(16), Asa(7), Agp(2), Ua(1)	Ao(13♀), Aa(6♀), 18♂ + Ob(22), Da(18)
Spondias purpurea●	243	61.3	1.7	Ao(4♀), 2♂	Ao(69♀), Af(4♀), 80♂ + Da(5), Ob(4)	—
ANNONACEAE						
Annona muricata●	4	4.8	4	—	—	Ad(1)
ARECACEAE						
Oenocarpus bacaba▲	1	0,8	1	—	—	0
CELASTRACEAE						
Cheiloclinium cognatum▲	16	2.7	8	1♂	—	Ah(1♀), 2♂
CHRYSOBALANACEAE						
Licania laxiflora▲	2	1.7	2	—	—	Ob(2)
EUPHORBIACEAE						
Manihot esculenta●	1	3.3	1	—	Ap(1)	—
FABACEAE						
Inga edulis●	643	100	30.6	Ad(184♀), 76♂	—	Ad(115♀), Af(2♀), 38♂
LAURACEAE						
Persea americana●	1	4.2	1	—	—	0
MALPIGHIACEAE						
Malpighia emarginata●	60	47.1	0.6	—	Ao(3♀), 1♂	Ao(5♀), 3♂
MALVACEAE						
Quararibea guianensis▲	11	4.4	5.5	Ao(5♀)	—	—
MELASTOMATACEAE						
Bellucia grossularioides▲	13	20.0	2.2	—	Ac(1♀), 2♂	—
MYRTACEAE						
Eugenia stipitata●	885	92.7	8.7	—	Ao(155♀), Af(10♀), 168♂	—
Plinia cauliflora●	15	40.0	2.5	—	Ao(6♀), 8♂	—
Psidium guajava●	2,242	94.4	14.8	Ast(45♀), Af(3♀), 51♂	—	Ast(454♀), Af(18♀), Ad(1♀), Ao(1♀), Azn(1♀), 595♂ + Da(11), Ob(1)
SAPOTACEAE						
Manilkara zapota●	86	31,7	2,3	—	Asp(4♀), Alp(1♀), 8♀	—
Pouteria caimito●	18	50,0	1,8	—	—	Ast(8♀), 1♂
Pouteria gardneri▲	3	6,7	3	—	Asp(1♀) + Da(1)	—

[a]Symbols following species names indicate ▲= native host; ● = introduced host.
[b]Infestation calculated as % FI = percentage of infested fruits; P/F = puparia per fruit.
[c]Fruit flies = Aa: *Anastrepha antunsesi*, Ac: *Anastrepha coronilli*, Ad: *Anastrepha distincta*, Af: *Anastrepha fraterculus*, Ah: *Anastrepha hastata*, Alp: *Anastrepha leptozona*, Ao: *Anastrepha obliqua*, Ap: *Anastrepha pickeli*, Asp: *Anastrepha serpentina*, Ast: *Anastrepha striata*, Azn: *Anastrepha zenildae*. Male flies (♂) were not identified to species.
[d]Parasitoids = Agp: *Aganaspis pelleranoi*, *Asa: Asobara anastrephae*, Da: *Doryctobracon areolatus*, Ob: *Opius bellus*, Ua: *Utetes anastrephae*.
[e]A dash (—) indicates that no species was found.

distincta Greene, *A. fraterculus*, *Anastrepha hastata* Stone, *Anastrepha leptozona* Hendel, *A. obliqua*, *Anastrepha pickeli* Lima, *Anastrepha serpentina* (Wiedemann), *A. striata*, and *A. zenildae* (Table 2).

The plant families Anacardiaceae, Myrtaceae, and Sapotaceae contained the greatest number of hosts of *Anastrepha* (3 species in each plant family). The plant families Annonaceae, Celastraceae, Euphorbiaceae, Fabaceae, Malpighiaceae, Malvaceae, and Melastomataceae each contained 1 host species (Table 2).

The highest percentages of infested fruits were recorded in *Inga edulis* Mart. (Fabaceae) (100%), *P. guajava* (94.4%), and *E. stipitata* (92.7%). In *I. edulis*, a high infestation rate was also obtained, as high as 30.6 puparia per fruit (Table 2). No adults emerged from the puparia of Tephritidae that were obtained from fruits of *Oenocarpus bacaba* Mart. (Arecaceae) and *Persea americana* Mill. (Lauraceae) (Table 2), whereas only the parasitoid *Opius bellus* Gahan (Hymenoptera: Braconidae) emerged from the puparia ontained from *Licania laxiflora* Fritsch (Chrysobalanaceae).

The most abundant species of *Anastrepha* were *A. striata* (508♀), *A. obliqua* (376♀), and *A. distincta* (301♀). The great majority of specimens of *A. striata* (98.2%) were from the infestation in *P. guajava*, but specimens were also obtained from *Pouteria caimito* (Ruiz & Pav.) Radlk. (Sapotaceae) and *S. mombin* (Table 2). *Anastrepha obliqua* was recorded in 7 hosts, predominately in *E. stipitata* (155♀) and *S. mombin* (121♀). *Anastrepha distincta* had the greatest incidence in *I. edulis* (184♀). *Anastrepha fraterculus* occurred in 2 species of Anacardiaceae, 2 of Myrtaceae and 1 of Fabaceae, being predominant in *P. guajava* (21♀). *Anastrepha serpentina* occurred in 2 species of Sapotaceae. *Anastrepha antunesi* occurred only in *S. mombin*. The species *A. coronilli*, *A. hastata*, *A. leptozona*, *A. pickeli*, and *A. zenildae* occurred in only 1 host each.

The species *A. antunesi*, *A. fraterculus*, *A. obliqua*, and *A. striata* were recorded in the 3 municipalities studied. *Anastrepha distincta* and *A. hastata* in 2 municipalities, and the others in only 1 (Table 3).

The species of parasitoids obtained were: *Asobara anastrephae* (Muesebeck) (Hymenoptera: Braconidae), *D. areolatus*, *O. bellus*, *Utetes anastrephae* (Viereck) (Hymenoptera: Braconidae), and *Aganaspis pelleranoi* (Brèthes) (Hymenoptera: Figitidae) (Table 2). *Opius bellus* was the most abundant species; we recovered 101 individuals from *Anastrepha* infesting 4 host plant species. *Doryctobracon areolatus* also was obtained from 4 plant species, but in lower abundance (67 specimens) than *O. bellus*.

Discussion

In this study, it was possible to characterize the host utilization by *Anastrepha* in areas with high diversity of fruit plants by means of broad sampling (78 plant species) on 3 fruit producing properties in the state of Amapá. Although the diversity of fruit plants available in the area was high, not all species were used as hosts (Table 1). According to Querino et al. (2010) and Hernández-Ortiz (1993), some species of fruit flies that occur in the Amazon have a high level of specificity in relation to hosts, with a strong preference for certain species or botanical families.

The percentages of infested fruits obtained from *I. edulis*, *P. guajava*, and *E. stipitata* are striking because they are high. However, it is not possible to compare them with most other studies carried out in Amapá because earlier studies were performed with pooled fruit

Table 3. Species of *Anastrepha* and their hosts in 3 municípalities in the state of Amapá, Brazil (Jan–Dec 2012).

	Host		Municípality		
Specie	Family	Species	Mazagão	Porto Grande	Santana
Anastrepha antunesi	Anacardiaceae	*Spondias mombin*	x	x	x
Anastrepha coronilli	Melastomataceae	*Bellucia grossularioides*		x	
Anastrepha distincta	Annonaceae	*Annona muricata*[a]			x
	Fabaceae	*Inga edulis*	x		x
	Myrtaceae	*Psidium guajava*			x
Anastrepha fraterculus	Anacardiaceae	*Spondias mombin*		x	
	Anacardiaceae	*Spondias purpurea*		x	
	Fabaceae	*Inga edulis*			x
	Myrtaceae	*Eugenia stipitata*		x	
	Myrtaceae	*Psidium guajava*	x		x
Anastrepha hastata	Celastraceae	*Cheiloclinium cognatum*	x		x
Anastrepha leptozona	Sapotaceae	*Manilkara zapota*[a]		x	
Anastrepha obliqua	Anacardiaceae	*Spondias dulcis*		x	
	Anacardiaceae	*Spondias mombin*	x	x	x
	Anacardiaceae	*Spondias purpurea*	x	x	
	Malpighiaceae	*Malpighia emarginata*		x	x
	Malvaceae	*Quararibea guianensis*[a]	x		
	Myrtaceae	*Eugenia stipitata*		x	
	Myrtaceae	*Plinia cauliflora*		x	
	Myrtaceae	*Psidium guajava*			x
Anastrepha pickeli	Euphorbiaceae	*Manihot esculenta*		x	
Anastrepha serpentina	Sapotaceae	*Manilkara zapota*		x	
	Sapotaceae	*Pouteria gardneri*[a]		x	
Anastrepha striata	Anacardiaceae	*Spondias mombin*		x	
	Myrtaceae	*Psidium guajava*	x		x
	Sapotaceae	*Pouteria caimito*			x
Anastrepha zenildae	Myrtaceae	*Psidium guajava*			x

[a]Unpublished association for Brazil (*Anastrepha* and host).

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samples, which prevents the estimation of the percentage of infested fruits. On the other hand, in relation to the number of puparia per fruit, the 3 species showed values similar to those already reported in Amapá (Silva et al. 2011b).

All recorded *Anastrepha* species had already been reported from the state of Amapá (Deus & Adaime 2013). In the present study, all 16 *P. guajava* samples collected were infested by *A. striata* (94.4% of the fruits). This close association of *A. striata* with *P. guajava* has been well documented in Amapá (Silva et al. 2011b) and elsewhere in the Brazilian Amazon (Silva et al. 2011c). It is a species widely distributed in Amapá, where 25 hosts (16 families) have already been registered (Silva et al. 2011b).

Anastrepha obliqua was obtained from 7 hosts, especially *E. stipitata* (41.1% of specimens) and *S. mombin* (32.6% of specimens). This species was also recorded from 4 other hosts, among them *Quararibea guianensis* Aubl. (Malvaceae). Infestation of *Q. guianensis* by an *Anastrepha* species has not previously been recorded.

Anastrepha distincta was the predominate fly infesting *I. edulis* (99.3% of the specimens), its main host in Amapá (Silva et al. 2011b). The species was also reared from *A. muricata*, which is a new association for Brazil.

Anastrepha fraterculus was recorded in 5 hosts, with 55.3% of its specimens being from *P. guajava.* The species is widely distributed in Amapá, although the population density is low (Deus & Adaime 2013).

Anastrepha antunesi was obtained only from *S. mombin*, a species with which it is frequently associated (Deus & Adaime 2013). In general, *A. antunesi* and *A. obliqua* are obtained from *S. mombin* fruits. Nascimento et al. (2015) collected 600 fruits of this plant and evaluated them individually. The authors recorded infestation by fruit flies in 151 fruits (25.2%) and obtained 298 puparia (mean of 1.97 puparia per fruit, with a maximum of 8 puparia per fruit). The simultaneous occurrence of *A. obliqua* and *A. antunesi* was recorded in only 2 of the 151 infested fruits (1.3%).

Anastrepha serpentina was obtained from fruits of *Manilkara zapota* (L.) P. Royen (Sapotaceae) and *Pouteria gardneri* (Mart. & Miq.) Baehni (Sapotaceae). The occurrence of *A. serpentina* in *P. gardneri* is not previosly reported for Brazil. It should be noted that *A. serpentina* has already been reported in *Pouteria gardneriana* (A. DC.) Radlk.(Sapotaceae) in the state of Goiás (Zucchi 2008), but that plant species does not occur in the Amazon region.

The species *A. coronilli*, *A. hastata*, *A. pickeli*, and *A. zenildae* were represented by a single specimen each, in hosts already reported to support them (Deus & Adaime 2013). However, *A. leptozona* was recorded here for the first time in *M. zapota* in Brazil.

The action of parasitoids on *Anastrepha* species was also recorded in this study. Of the 179 specimens obtained, 56.4% were *O. bellus*, 38.0% *D. areolatus*, 3.9% *A. anastrephae*, 1.1% A*. pelleranoi*, and 0.6% *U. anastrephae* (Table 2). Together, *O. bellus* and *D. areolatus* accounted for 94.4% of the total specimens obtained. Due to their abundance, they are the species with the greatest potential to control the population of fruit flies under the conditions in Amapá (Deus & Adaime 2013). *Opius bellus* and *D. areolatus* occurred in the 3 municipalities studied. The other species occurred only in Porto Grande (Table 2). We obtained 81.0% of the parasitoid specimens reported in this study from *S. mombin*. This plant plays an important role as a natural reservoir of the fruit fly parasitoid populations in Amapá, which deserves further study (Sousa et al. 2016).

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