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article

Pioneer tree species as fruit flies parasitoids reservoir in the Brazilian Amazon

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Abstract: The objective of this study was to evaluate the potential of the pioneer plant species *Bellucia grossularioides* (L.) Triana (Melastomataceae) to act as a reservoir for parasitoids of fruit flies in the Brazilian Amazon. We collected 48 samples of fruits (total of 4,012 fruits, 43.98 kg) during the months of July, August and September of 2013, in 15 of the 16 municipalities of Amapá State, Brazil. All samples showed infestation by fruit flies, with rates varying from 60.6 to 239.1 puparia/kg of fruit (mean of 106.8 puparia/kg of fruit). The percentage of emergence varied 18.6 to 64.3% (mean of 39.9%). Specimens of *Anastrepha coronilli* Carrejo & González (Diptera: Tephritidae) were obtained from all samples collected. Specimens of *Neosilba* (Diptera: Lonchaeidae) were obtained from five samples, where they were represented by *Neosilba bella* Strikis & Prado and *Neosilba glaberrima* (Wiedemann). The mean percentage of parasitism was 12.8%, varying 4.7 to 26.7%. Four species of parasitoids were obtained: *Doryctobracon areolatus* (Szépligeti), *Doryctobracon* sp.2, *Opius bellus* Gahan (Braconidae) and *Aganaspis pelleranoi* (Brèthes) (Figitidae). *Doryctobracon areolatus*, present in all municipalities sampled, was the most abundant species. Considering that *B. grossularioides* is a plant species that is abundant in the area sampled, its relevance with respect to the maintenance of the population of parasitoids is discussed in the context of the integrated management of fruit flies in the Amazon.

Keywords: *Biological control, Natural enemies, Anastrepha coronilli, Doryctobracon areolatus.*

Espécie de árvore pioneira como reservatório de parasitoides de moscas-das-frutas na Amazônia brasileira

Resumo: O objetivo deste trabalho foi avaliar o potencial da espécie vegetal pioneira *Bellucia grossularioides* (L.) Triana (Melastomataceae) para atuar como reservatório de parasitoides de moscas-das-frutas na Amazônia brasileira. Foram realizadas coletas de 48 amostras de frutos (4.012 frutos, 43,98 kg) durante os meses de julho, agosto e setembro de 2013, em 15 dos 16 municípios do estado do Amapá, Brasil. Todas as amostras apresentaram infestação por dípteros, com índices que variaram de 60,6 a 239,1 pupários/kg de fruto (média de 106,8 pupários/kg de fruto). O percentual de emergência variou de 18,6% a 64,3% (média de 39,9%). Exemplares de *Anastrepha coronilli* Carrejo & González (Diptera: Tephritidae) foram obtidos de todas as amostras coletadas. Exemplares de *Neosilba* (Diptera: Lonchaeidae) foram obtidos de cinco amostras, sendo representadas por *Neosilba bella* Strikis & Prado e *Neosilba glaberrima* (Wiedemann). O percentual médio de parasitismo foi de 12,8%, variando de 4,7% a 26,7%. Quatro espécies de parasitoides foram obtidas: *Doryctobracon areolatus* (Szépligeti), *Doryctobracon* sp.2, *Opius bellus* Gahan (Braconidae) e *Aganaspis pelleranoi* (Brèthes) (Figitidae). *Doryctobracon areolatus*, presente em todos os municípios amostrados, foi a espécie mais abundante. Considerando-se que *B. grossularioides* é uma espécie vegetal abundante na área amostrada, sua relevância quanto à manutenção da população de parasitoides é discutida no contexto do manejo integrado de moscas-das-frutas na Amazônia.

Palavras-chave: *Controle biológico, Inimigos naturais, Anastrepha coronilli, Doryctobracon areolatus.*

Introduction

Fruit flies (Diptera: Tephritidae) are among the most important pests worldwide due to their economic impacts and the severe quarantine restrictions imposed by many countries to prevent their entry (Aluja 1994, Follett & Neven 2006, Aluja & Mangan 2008). The information needed to understand the biology, ecology and evolution of these insects should be determined in areas of practically unchanged native vegetation, especially when one considers that the rapid deforestation of the tropics may be causing the disappearance or even extinction of many species of fruit flies, consequently

threatening the associated native parasitoid species (Hymenoptera) (Aluja 1999, Aluja et al., 2003). These insects, especially those belonging to the family Braconidae, play an important role in the natural biological control of fruit flies, considered as pests (López et al., 1999, Ovruski et al., 2000).

In a study carried out in the state of Veracruz, Mexico, López et al. (1999) demonstrated the need to protect native vegetation due to its important role as a reservoir of fruit flies parasitoids. The authors reported that native plants in the wild harbor significantly more parasitoids per fruit than do cultivated plants, corroborating the work of Sivinski (1991) and Hernández-Ortíz et al. (1994).

López et al. (1999), in summarizing studies with parasitoids in various countries, indicated that: 1) *Doryctobracon areolatus* (Szépligeti) (Hymenoptera: Braconidae) is the most abundant and widespread native parasitoid of *Anastrepha*; 2) most parasitoid species are generalists (they attack many *Anastrepha* species); and 3) many native species are found preferentially parasitizing *Anastrepha* larvae in wild native fruit trees.

Aluja (1999) suggested that in regions where producers have few resources, the following actions can be promoted as alternatives to the wide use of insecticides: 1) the preservation of habitats where parasitoids develop; 2) artificial increase of certain reservoirs of parasitoids and species of trees promoting and multiplying biodiversity. More recently, Aluja et al. (2014) proposed three categories of fruit plants of interest for the conservative biological control of fruit flies: 1) parasitoid multiplier plants: species that serve as alternative hosts for fruit flies pests when their commercial hosts are not available, in which they are exceptionally vulnerable to parasitism; 2) parasitoid reservoir plants: native or introduced trees in whose fruits non-pest fruit flies serve as hosts of generalist parasitoids that are capable of attacking tephritid pests on other commercially grown fruit species; and 3) pest-based parasitoid reservoir plants: native or introduced species that are not economically important locally but harbor fruit flies that would otherwise be pests and serve as hosts for parasites of major pests in the vicinity.

Bellucia is a Neotropical plant genus comprising seven species (Renner 1986, 1987). In general, activities such as timber extraction, road construction and pasture formation have provided excellent habitats for species of this genus. *Bellucia grossularioides* (L.) Triana (Figure 1) occurs from Mexico to the Brazilian Amazon. It grows in areas of altered and unchanged vegetation, being adapted to a variety of soil types. It is among the most important pioneer species in terms of number of individuals per area in the Central Amazon. It flowers and bears fruit for long periods or continuously throughout the year. Eventually, fruits are consumed by animal species (especially mammals) and, less frequently, by humans. They usually reach a maximum height of 20 to 25 m. The minimum diameter for the beginning of the reproductive phase is 7.8 cm. The main dispersants are birds and monkeys (Bentos et al., 2008, Santos et al., 2012).

Anastrepha coronilli Carrejo & González (Diptera: Tephritidae) is a species of the *fraterculus* group, considered to be of no economic importance, especially associated with Melastomataceae species (Norrbom et al., 2013). In the Brazilian Amazon, some surveys were carried out to determine the infestation rates of *B. grossularioides* by *A. coronilli* and associated parasitoids. Parasitism of up to 28% of puparia was recorded in samples from Ferreira Gomes, Amapá State (Deus et al., 2013). The species of parasitoids recorded were: 1) Braconidae - *Asobara anastrephae* (Muesebeck) (Deus et al., 2009), *Doryctobracon areolatus* (Bomfim et al., 2007, Deus et al., 2009, Pereira 2009, Pereira et al., 2010, Marsaro Júnior et al., 2011, Ronchi-Teles et al., 2011, Silva et al., 2011a, Deus et al., 2013, Dutra et al., 2013), *Doryctobracon crawfordi* (Viereck) (Deus et al., 2013), *Doryctobracon* sp. (Bomfim et al., 2007), *Opius bellus* Gahan (Dutra et al., 2013, Adaime et al. 2017) and *Utetes anastrephae* (Viereck) (Dutra et al., 2013); 2) Figitidae - *Aganaspis nordlanderi* Wharton (Ronchi-Teles et al., 2011) and *Aganaspis pelleranoi* (Brèthes) (Deus et al., 2013, Dutra et al., 2013). In all studies carried out in the region, *D. areolatus* was the predominant species.

This work was carried out to determine the potential of *B. grossularioides* to act as a reservoir of fruit flies parasitoids in the Amapá State in the Brazilian Amazon.

Material and Methods

1. Geographic area covered

The Amapá State (area of 143,453.70 km^2) is situated in Eastern Amazon and is considered the most preserved of the country. It is bordered to the south and west by Pará State, to the east by the Atlantic Ocean, to the north by French Guiana and to the northwest by Suriname (Figure 2) (Porto 2007). The climate in the region, according to the Koëppen-Geiger classification, is Aw (tropical savanna) and Am (tropical monsoon) types, with mean annual precipitation between 2,300 and 2,400 mm (Pell et al., 2007). The rainy season occurs from January to June and a characteristically dry period is more frequent from September to November. The mean annual temperature is 26ºC (IBGE 2011). The region is composed of domains of cerrado, floodplain forest, upland forest and the transition forests cerrado/forest and cerrado/floodplain forest (IEPA 2002).

Figure 1. *Bellucia grossularioides*. A) Flowering plant, B) fruits in ventral view. Photographs: Jonh Carlo Reis dos Santos.

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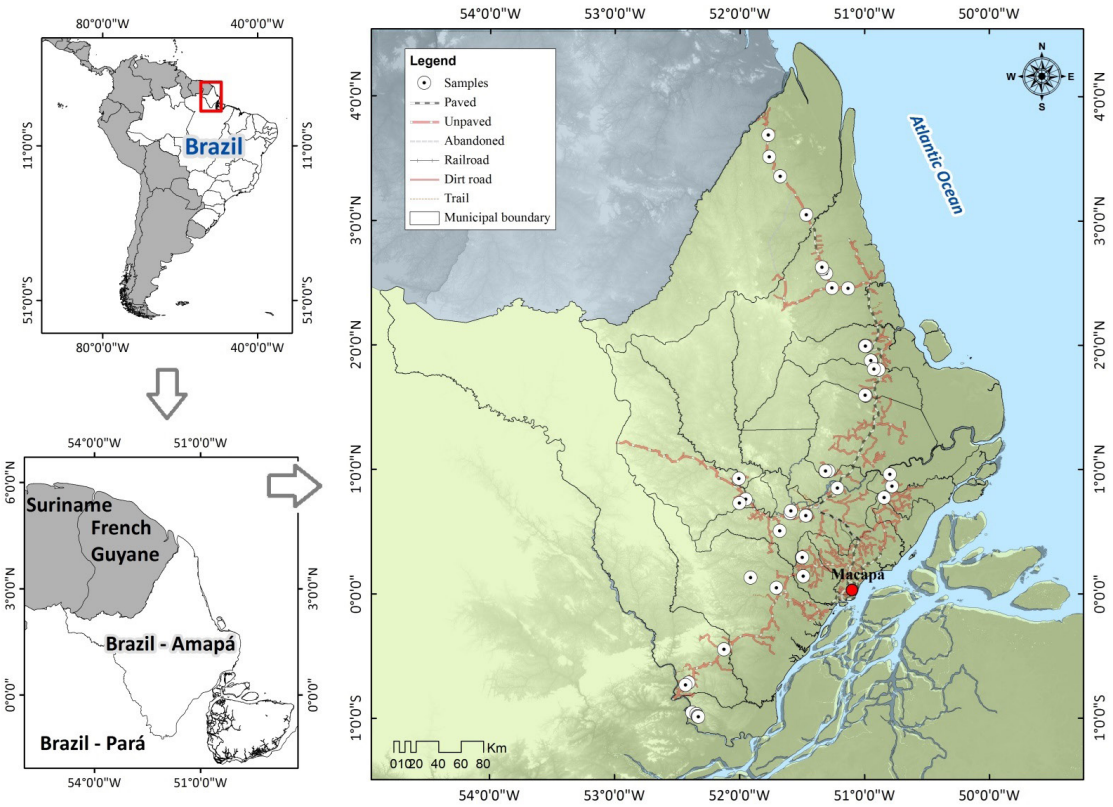

Figure 2. Location of sampling points for *Bellucia grossularioides* in various municipalities of Amapá State (July to September of 2013).

2. Collection and processing of samples

Samples of *B. grossularioides* fruits were collected during July, August and September of 2013 in 15 of the 16 municipalities of Amapá State (Table 1 and Figure 2). The collections were made especially in the side of vicinal roads, locating plants with a good amount of fruits. Each sample was composed of fruits of the same plant, whose size depended on the availability of fruits. The fruits were collected directly from the plant and ground (intact fruits, freshly fallen), weighed on a digital balance and placed in plastic jars (14 cm in diameter), under on a thin layer of moistened sand, covered with organza and an open lid. The geographical coordinates of the sampling points were determined with the aid of a GPS.

In the laboratory of Plant Protection at Embrapa Amapá, the fruits were transferred to plastic trays, under a layer of moistened sand, covered with organza and fastened in place with rubber bands. Every seven days the samples were examined. The puparia obtained from each sample were packed in plastic bottles (6.5 cm in diameter) containing a thin layer of moist vermiculite. The bottles were kept in climatized chambers under controlled conditions of temperature (26±0.5ºC), relative humidity (70 ± 10%) and photophase (12 hours) and observed daily to determine the number of fruit flies and parasitoids. The emerged adults were preserved in 70% ethanol for later identification.

3. Identification of insects

The insects were identified using the keys of Zucchi (2000), Canal and Zucchi (2000), Marinho et al. (2011), Strikis (2011) and Zucchi et al. (2011). Voucher specimens were deposited in the Plant Protection Laboratory of Embrapa Amapá.

Table 1. Period collection of *Bellucia grossularioides* in various municipalities of Amapá State (July to September of 2013).

Municipalities*	Collection dates
Amapá	8/14/2013 and 8/16/2013
Calçoene	7/29/2013 and 7/31/2013
Cutias do Araguari	8/23/2013
Ferreira Gomes	8/16/2013
Laranjal do Jari	7/18/2013 and 9/5/2013
Macapá	8/23/2013
Mazagão	9/5/2013
Oiapoque	7/30/2013
Pedra Branca do Amapari	9/3/2013
Porto Grande	7/20/2013 and 8/6/2013
Pracuúba	8/16/2013
Santana	9/17/2013
Serra do Navio	8/13/2013
Tartarugalzinho	8/15/2013 and 8/16/2013
Vitória do Jari	9/6/2013

*In alphabetical order.

4. Data analysis

We calculated: 1) infestation rate (number of puparia obtained in the sample ÷ weight of the sample), expressed as number of puparia/kg of fruit; 2) emergence percentage [(number of emerged adults ÷ number of puparia obtained in the fruit) x 100], expressed as a percentage; and 3) percentage of parasitism in pupae [(number of emerged parasitoids ÷ number of puparia obtained) x 100], expressed as a percentage.

Results

Forty-eight samples of *B. grossularioides* fruits (4,012 fruits, 43.98 kg) were collected, covering an extensive area of Amapá State (Table 2, Figure 1). All samples showed infestation by fruit flies (Table 2). A total of 4,307 puparia were obtained, with infestation rates varying from 60.6 to 239.1 puparia/kg of fruit (mean of 106.8 puparia/kg of fruit).

The emergence percentage ranged 18.6 to 64.3%, with a mean of 39.9% (Table 2). Specimens of *A. coronilli* Carrejo & González, 1993 (Diptera: Tephritidae) were obtained from all collected samples, totaling 571♀ and 548♂. Specimens of *Neosilba* (Diptera: Lonchaeidae) were obtained from five samples, represented by *Neosilba bella* Strikis & Prado (14♂) and *N. glaberrima* (Wiedemann) (1♂).

The mean percentage of parasitism was 12.8%, ranging 4.7 to 26.7% (Table 2). Only three samples (6.3% of the total of 48) did not show parasitism. Four species of parasitoids were obtained: *Doryctobracon areolatus* (582 specimens), *Doryctobracon* sp.2 (1), *Opius bellus* (3) (Braconidae) and *Aganaspis pelleranoi* (3) (Figitidae). *Doryctobracon areolatus*, present in all municipalities sampled, was the most abundant species

Discussion

1. Infestion rate and percentage of parasitism

In the state of Amapá, some other surveys had been carried out to determine the infestation rates of *B. grossularioides* by fruit flies and associated parasitoids. Table 3 shows data for 11 municipalities, with 97.8% of the samples being infested (the highest infestation rate was 242.5 puparia/kg, in samples from Mazagão). Only *A. coronilli* specimens were obtained.

Additionally, Jesus-Barros et al. (2012) carried out extensive fruit sampling in five municipalities of Amapá (Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba and Tartarugalzinho). Thirty samples (1,892 fruits, 21.16 kg) of *B. grossularioides* were collected, and 28 of them were infested by fruit flies. A total of 636 puparia (infestation rate of 30.06 puparia/kg) were obtained, from which *A. coronilli* (225), *A. striata* Schiner (24) and *A. antunesi* Lima (3) emerged. The fact that *A. striata* and *A. antunesi* specimens were found is noteworthy in the present study. However, in relation to the total number of females obtained, the species corresponded to only 9.5 and 1.19%, respectively. In the state of Rondônia, Pereira et al. (2010) obtained only one specimen of *A. striata* in fruits of *B. grossularioides*.

In other states of the Brazilian Amazon, few samples of *B. grossularioides* were collected (Table 4). The highest infestation rate recorded was 141.2 puparia/kg, in fruits from the state of Rondônia (Pereira et al., 2010).

The most frequent host of *A. coronilli* is actually *B. grossularioides*, and it is also found in *Bellucia dichotoma* Cogn. (Table 5). Four other hosts were also recorded for the species in the Brazilian Amazon, and of them, only guava (*Psidium guajava* L.) is of commercial importance. However, it should be noted that the frequency and abundance of *A. coronilli* in guava is very low. In intensive work in Amapá, Jesus-Barros et al. (2012) collected 255 guava samples (9,657 fruits, 425.97 kg), of which 222 showed infestation by fruit flies. A total of 17,531 puparia were obtained (infestation rate of 41.16 puparia/kg), from which six species of *Anastrepha* emerged: *A. striata* (4176♀), *A. fraterculus* (Wiedemann) (95♀), *A. coronilli* (16♀), *A. parishi* Stone (15♀), *A. distincta* Greene (13♀) and *A. zenildae* Zucchi (2♀). It can be seen that only 0.37% of females obtained from guava in that study were *A. coronilli*. In a survey in Rondônia, Pereira et al. (2010) obtained only one specimen of *A. coronilli* in guava.

In Brazil, records of species of lance flies associated with fruit species are scarce, because in many studies their presence is neglected. However, the classification of some species as pests has recently attracted the attention of researchers (Veloso et al., 1994, Uchôa-Fernandes & Zucchi 1999, Uchôa-Fernandes et al., 2002, Bittencourt et al., 2006). Recent studies indicate that larvae of some species of Lonchaeidae colonize a larger number of fruit species than larvae of flies of the family Tephritidae (Ferreira et al., 2003).

Recently, Strikis et al. (2011) collected available information on Lonchaeidae in the Brazilian Amazon and published new records of lance flies obtained from wild and cultivated fruit species. So far, only *N. pendula* (Bezzi) had been reported in fruits of *B. grossularioides* in Cantá, Roraima. In the present work the species *N. bella* and *N. glaberrima* are reported for the first time in this plant species (Table 5). Therefore, it is possible that these species use fruits of *B. grossularioides* as an alternative host.

The results indicated considerable parasitism (mean of 12.8% of parasitized puparia) (Table 2). In addition, 93.7% of the samples had parasitized puparia (43 of 48 samples). Four species of parasitoids were obtained, where

Table 2. Infestation rates of *Bellucia grossularioides* by fruit flies and associated parasitoids in various municipalities of Amapá State (July to September of 2013).

Municipalities	SC/IS[1]	Fruits (n)	Weight (kg)	P[2] (n)	Infestation (PP/kg)	Emergence (%)	Tephritidae[3] (n)	Lonchaeidae[4] (n)	PP[5] (%)	Parasitoids[6] (n)
Amapá	5/5	475	5.73	437	76.3	37.1	Ac (34♀), 42♂		19.7	Da (86)
Calçoene	5/5	491	5.96	397	66.6	53.9	Ac (40♀), 57♂	Nb (8♂), Ng (1♂), 2♀	26.7	Da (106)
Cutias do Araguari	2/2	132	1.06	85	80.0	36.5	Ac (12♀), 14♂		5.9	Da (5)
Ferreira Gomes	1/1	162	1.61	385	239.1	33.2	Ac (34♀), 31♂	Nb (1♂)	16.1	Da (60), Ob (1), Ap (1)
Laranjal do Jari	3/3	297	3.02	452	149.7	18.6	Ac (28♀), 31♂		5.5	Da (25)
Macapá	1/1	90	0.69	55	79.7	23.6	Ac (1♀), 3♂		16.4	Da (9)
Mazagão	2/2	175	1.26	168	133.3	64.3	Ac (38♀), 51♂	1♀	10.7	Da (18)
Oiapoque	4/4	343	4.29	349	81.4	34.7	Ac (41♀), 41♂	Nb (5♂), 6♀	8.0	Da (28)
Pedra Branca do Amapari	3/3	219	3.48	279	80.2	54.5	Ac (72♀), 67♂		4.7	Da (11), Ob (2)
Porto Grande	5/5	478	5.59	627	112.2	42.3	Ac (79♀), 70♂	1♀	18.3	Da (114), Ap (1)
Pracuúba	2/2	126	1.12	68	60.7	23.5	Ac (1♀), 2♂		19.1	Da (13)
Santana	4/4	324	3.44	344	100.0	46.2	Ac (76♀), 51♂		9.3	Da (32)
Serra do Navio	1/1	63	0.53	81	152.8	45.7	Ac (16♀), 15♂		7.4	Da (6)
Tartarugalzinho	5/5	312	3.60	313	86.9	35.5	Ac (36♀), 32♂		14.4	Da (42), Ob (1), Dsp2 (1), Ap (1)
Vitória do Jari	5/5	325	2.60	267	102.7	49.4	Ac (63♀), 41♂		10.5	Da (27), Ob (1)
Total	48/48	4012	43.98	4307	106.8*	39.9*	Ac (571♀), 548♂	Nb (14♂), Ng (1♂), 10♀	12.8*	Da (582), Ob (5), Ap (3), Dsp2 (1)

[1]SC/IS: samples collected/infested samples, [2]P: puparia; [3]♀ identified (Ac: *Anastrepha coronilli*); [4]♂ identified (Nb: *Neosilba bella;* Ng: *Neosilba glaberrima*); [5]PP: percentage of parasitism; [6]Da: *Doryctobracon areolatus*; Dsp2: *Doryctobracon* sp2; Ob: *Opius bellus*; Ap: *Aganaspis pelleranoi.* *mean for municipalities.

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Table 3. Occurrence of *Anastrepha coronilli* in fruits of *Bellucia grossularioides* and associated parasitoids in Amapá State, Brazil.

Municipalities	SC/IC*	Fruits (n)	Weight (kg)	Puparia obtained (n)	*A. coronilli* (n)	Parasitoids (n)	Infestation (puparia/kg)	PP* (%)	References**
Pedra Branca do Amapari	7/7	349	5.80	272	66♀, 69♂	*Asobara anastrephae* *Doryctobracon areolatus*	46.9	15.80	Deus et al. (2009)
Serra do Navio	4/4	276	6.15	103	28♀, 31♂	*Asobara anastrephae* *Doryctobracon areolatus*	16.8	12.62	Deus et al. (2009)
Laranjal do Jari	4/4	524	5.05	112	17♀, 21♂	*Doryctobracon areolatus*	22.2	11.6	Silva et al. (2011a)
Vitória do Jari	3/3	335	2.79	56	9♀, 19♂	-	20.1	0	Silva et al. (2011a)
Amapá	2/2	41	0.50	16	5♀, 7♂	*Doryctobracon areolatus*	32.0	12.50	Deus et al. (2013)
Calçoene	2/2	38	0.37	14	6♀, 5♂	-	37.8	0	Deus et al. (2013)
Ferreira Gomes	2/2	93	0.79	175	22♀, 27♂	*Doryctobracon areolatus* *Aganaspis pelleranoi*	221.5	28.00	Deus et al. (2013)
Mazagão	2/2	69	0.47	114	24♀, 30♂	*Doryctobracon areolatus*	242.5	15.78	Deus et al. (2013)
Pedra Branca do Amapari	2/2	13	0.57	18	3♀, 5♂	*Doryctobracon areolatus*	31.6	5.55	Deus et al. (2013)
Porto Grande	7/6	205	2.00	398	73♀, 109♂	*Doryctobracon areolatus* *Aganaspis pelleranoi* *Doryctobracon crawfordi*	199.0	12.56	Deus et al. (2013)
Santana	1/1	7	0.05	2	1♀, 1♂	-	40.0	0	Deus et al. (2013)
Serra do Navio	2/2	110	1.20	202	43♀, 44♂	*Doryctobracon areolatus* *Aganaspis pelleranoi*	168.3	11.38	Deus et al. (2013)
Oiapoque	3/3	142	1.70	88	19♀, 17♂	*Doryctobracon areolatus*	51.8	11.4	Adaime et al. (2017)
Calçoene	4/4	140	1.89	80	15♀, 24♂	*Doryctobracon areolatus* *Opius bellus*	42.3	16.3	Adaime et al. (2017)
Total	45/44	2342	29.33	1650	-	-	-	-	-

*SC/IS: samples collected/infested samples, PP: percentage of parasitism.

** In chronological order.

Table 4. Occurrence of parasitoids in fruits of *Bellucia grossularioides* infested by *Anastrepha coronilli* in the Brazilian Amazon.

States Municipalities	SC/IS*	Fruits (n)	Weight (kg)	Puparia obtained (n)	Infestation (P/kg)*	Parasitoids (n)	PP* (%)	References
Acre Capixaba	1/1	50	0.60	49	81.7	*Doryctobracon areolatus*	10.20	Pereira et al. (2010)
Amazonas Manaus	1/1	219	2.20	151	68.6	*Doryctobracon areolatus*	8.61	Dutra et al. (2013)
Amazonas Manaus	1/1	758	5.03	68	13.5	*Doryctobracon areolatus* *Aganaspis nordlanderi*	11.76	Ronchi-Teles et al. (2011)
Amazonas Presidente Figueiredo	1/1	226	1.50	133	88.7	*Doryctobracon areolatus* *Opius bellus* *Utetes anastrephae* *Aganaspis pelleranoi*	11.28	Dutra et al. (2013)
Pará Santarém Belterra	6/6	203	1.90	149	78.4	*Doryctobracon areolatus*	2.7	Pereira (2009)
Rondônia Ouro Preto do Oeste	4/4	131	0.85	120	141.2	*Doryctobracon areolatus*	2.50	Pereira et al. (2010)
Roraima Cantá	1/1	32	0.50	16	32.0	*Doryctobracon areolatus*	12.5	Marsaro Júnior et al. (2011)
Tocantins Palmas	nd	nd	nd	nd	nd	*Doryctobracon areolatus* *Doryctobracon* sp.	nd	Bomfim et al. (2007)

*SC/IS: samples collected/infested samples, P/kg: puparia/kg, PP: percentage of parasitism, nd: not determined.

Doryctobracon sp.2 was recorded for the first time in larvae of *A. coronilli* in fruits of *B. grossularioides*. It is a species that has been recently collected in Brazil but not yet formally described (Marinho et al., 2011). In other studies carried out in Amapá, the highest rate of parasitism of *A. coronilli* puparia was 28.0%, obtained in Ferreira Gomes. In most samples, the rate obtained has been greater than 10% (Table 3). Jesus-Barros et al. (2012) found parasitism of 5.97%, with *D. areolatus* (37 specimens) and *A. anastrephae* (1) being collected in five municipalities of Amapá. In other places in the Brazilian Amazon, the highest parasitism rate observed was 12.5% in Roraima (Table 4) (Marsaro Júnior et al., 2011).

It should be considered that the rates of parasitism found in studies in which fruits were collected in the field and placed under laboratory

Table 5. Distribution and hosts of *Anastrepha coronilli* in the Brazilian Amazon.

Hosts*	States	References
Bellucia dichotoma (Melastomataceae) (= *Bellucia imperialis*)	Amazonas	Costa (2005)
	Amapá	Silva et al. (2009)
Bellucia grossularioides (Melastomataceae)	Amapá	Ronchi-Teles et al. (1996)
	Amazonas	Ronchi-Teles et al. (1998)
	Pará	Pereira (2009)
	Tocantins	Bomfim et al. (2007)
Dolicarpus sp. (Dileniaceae)	Amazonas	Costa (2005)
Guatteria discolor (Annonaceae)	Amazonas	Costa (2005)
Loreya mespiloides Miq. (Melastomataceae)	Roraima	Marsaro Júnior et al. (2010)
Mouriri dimorphandra (Memecylaceae)	Amazonas	Costa (2005)
Psidium guajava (Myrtaceae)	Amapá	Jesus-Barros et al. (2012)
	Rondônia	Pereira et al. (2010)

*In alphabetical order.

Table 6. Parasitoids in fruits of *Bellucia grossularioides* infested by *Anastrepha coronilli* in the Brazilian Amazon.

Species*	States	References
Aganaspis nordlanderi	Amazonas	Ronchi-Teles et al. (2011)
Aganaspis pelleranoi	Amapá	Deus et al. (2013) and present work
	Amazonas	Dutra et al. (2013)
Asobara anastrephae	Amapá	Deus et al. (2009)
Doryctobracon areolatus	Amapá	Deus et al. (2009), Deus et al. (2013), Silva et al. (2011a) and present work
	Amazonas	Dutra et al. (2013) and Ronchi-Teles et al. (2011)
	Pará	Pereira (2009)
	Rondônia	Pereira et al. (2010)
	Roraima	Marsaro Júnior et al. (2011)
	Tocantins	Bomfim et al. (2007)
Doryctobracon crawfordi	Amapá	Deus et al. (2013)
Doryctobracon sp.	Tocantins	Bomfim et al. (2007)
Doryctobracon sp2.	Amapá	Present work
Opius bellus	Amapá	Adaime et al. (2017)
	Amazonas	Dutra et al. (2013)
Utetes anastrephae	Amazonas	Dutra et al. (2013)

*In alphabetical order.

conditions are not real because the fruits were removed from the natural environment, possibly with eggs and larvae of first and second instars of fruit flies. Thus, when immatures are removed from the field, they are no longer likely to be parasitized (Uchôa-Fernandes et al., 2003). Therefore, it is estimated that the actual parasitism rate in *A. coronilli* larvae infesting *B. grossularioides* fruits is even higher.

In the present work, nine species of fruit fly parasitoids (two from Figitidae and seven from Braconidae) have been found on *B. grossularioides* in the Brazilian Amazon (Table 6).

2. Implications for the integrated management of fruit flies

The results demonstrate the capacity of *B. grossularioides* to act as a fruit fly parasitoid reservoir (as proposed by Aluja et al., 2014) in the state of Amapá and, therefore, in the Brazilian Amazon. The collections have been more extensive than in any other state in the region. The plant species clearly plays a fundamental role in the maintenance of the fruit fly parasitoid population. It is a pioneer species that is widely distributed and adapted to various soil conditions. Because it is not a species of economic interest, the biological control of fruit flies is favored, since the possibility of removal of the plants due to some commercial interest therefore does not seem to be a threat. Although fruits are consumed by animals, especially mammals, there does not seem to be considerable reduction in the amount of fruits on the ground, which potentially contains parasitoids. In general, when the infested fruits fall, the larvae abandon it and enter the soil, to proceed to the pupa phase. Thus, even if a certain amount of fruit is consumed, the parasitoids that infested fly larvae would be preserved, since they would already be in the pupa stage, in the soil.

In summary, the results suggest that *B. grossularioides* is a species that can be conserved in its environments of occurrence for maintenance of the parasitoid population. Another possibility that presents itself is to cultivate this plants species around orchards. The plants would act as reservoirs of parasitoids, which, being generalists, can help to reduce populations of pest species.

Another important point is that *B. grossularioides* hosts almost exclusively *A. coronilli*, a species of no economic importance. Thus, when considering the amount of fruits sampled and the total number of *A. coronilli* specimens obtained, the number of adults of other species becomes very small. Still, it is suggested that further, intensive surveys be conducted for a whole year to substantiate this notion.

It is therefore possible to attempt to develop systems through which parasitoid reservoirs can be managed to naturally increase the number of parasitoids in areas of native vegetation (López et al., 1999). Thus, cultivation or maintenance of the natural populations of *B. grossularioides* could contribute to increasing the community of fruit flies parasitoids without the risk of increasing the population of pest species.

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3. Research demands

The results obtained open new perspectives of research for the better understanding of the tritrophic interaction between *B. grossularioides*, *A. coronilli* and associated parasitoids. Studies based on individualized fruits could help considerably in this regard, as detailed by Silva et al. (2011b). Undoubtedly, it is essential to study the phenology of *B. grossularioides* in local conditions of natural occurrence, detailing the fruiting period, the consequent infestation by fruit flies and the corresponding parasitism rate throughout the year. To quantify the fruits produced per plant per year is a determinant for estimating the contribution of each individual as parasitoid reservoir.

Moreover, it is also important to study the biology of *A. coronilli* and its behavioral aspects. In general, studies on species of no economic importance have been neglected. The main aspects to be studied are feeding and reproduction behaviors, as well as biological aspects, especially reproductive potential, immature development time and adult longevity.

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Authors' Contributions

RA and EGD contributed to the concept and design of the study, to data analysis and interpretation, and to the manuscript preparation. MSMS and JCRS contributed to the data collection, to the critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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