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Scientific Note

First record of papaya as host of carambola fruit fly in Brazil

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Abstract. In this work we report for the first time in Brazil the occurrence of carambola fruit fly *Bactrocera carambolae* Drew & Hancock, 1994 (Diptera: Tephritidae) in fruits of *Carica papaya* L., from samples collected in the municipalities of Almeirim, state of Pará, and Mazagão, state of Amapá. These findings are discussed in the context of Brazilian fruit growing.

Keywords: *Bactrocera carambolae*, quarantine pest, fruit production, Amazon.

The carambola fruit fly (CFF), *Bactrocera carambolae* Drew & Hancock, 1994 (Diptera: Tephritidae), native to Southeast Asia (Vijaysegaran & Oman 1991), is an invading species in South America, reported in Suriname, French Guiana, Guyana, and Brazil (Malavasi 2015). It is a quarantine pest present in Brazil, initially detected in 1996, in the state of Amapá (Silva et al. 2004), nowadays present also in some locations in the states of Pará and Roraima, under official control by the Ministry of Agriculture and Livestock (Brasil 2018). In the event of CFF dispersion to areas producing fresh fruit destined for export, quarantine barriers would be imposed by importing countries (Silva et al. 2004; Godoy et al. 2011; Lemos et al. 2014; Ferreira & Rangel 2015; Miranda & Adami 2015).

Knowing the fruits species used by this pest for the development of its larvae is crucial for the inspection and control actions carried out by official plant health defense agencies in Brazil (Lemos et al. 2014; Jesus-Barros et al. 2015; Belo et al. 2020). Therefore, intense fruit collection in natural field conditions has already been conducted in the Amapá State since 2004, resulting in 30 host plant species of CFF reported, belonging to 12 botanical families (Adaime et al. 2023; Costa et al. 2023a; 2023b).

Papaya cultivation has significant socioeconomic importance in Brazil, covering 26,431 ha, with an average yield of 41.9 tons/ha, totaling approximately 1,107,761 tons, with a total estimated revenue of R$ 2.40 billion. The main producing states in Brazil are Espíriro Santo (426,616 tons in 6,918 ha), followed by Bahia (316,163 tons in 9,238 ha) and Ceará (114,299 tons in 1,611 ha) (IBGE 2022). Furthermore, papaya represents an important component of Brazilian exports, as in 2023, papaya was the 8th most exported fruit in Brazil, with a value of US$ 53,1 million (R$ 276 million) and an export volume of 37,852.46 tons (Agrostat 2024).

We did a fruit sampling of *Carica papaya* L. (Caricaceae) in February and March 2022 in the district of Monte Dourado, municipality of Almeirim, state of Pará, in two sites (Fig. 1): Site A (private area of the company Jari Celulose S.A., where there were plants that grew spontaneously, very etiolated, as shown in Fig. 2A-B) and Site B (village of Munguba, single plants in the urban area). Also, another sample of fruits was collected in the municipality of Mazagão, state of Amapá (Site C), in a single plant in the urban area, in March 2024.

In each site, before collection, some fruits collected from the ground were dissected to check for the existence of larvae (Fig. 2C). Samples were taken randomly, collecting ripened or ripening fruit directly from the plants or freshly fallen to the ground. Each sample was composed of an amount of fruits evaluated in groups, following the method described by Silva et al. (2011). After being weighed on a digital scale, they were placed in plastic trays (30.3 × 22.1 × 7.5 cm), over a 2 cm layer of moistened vermiculite, covered with organza, which was secured with an elastic band.

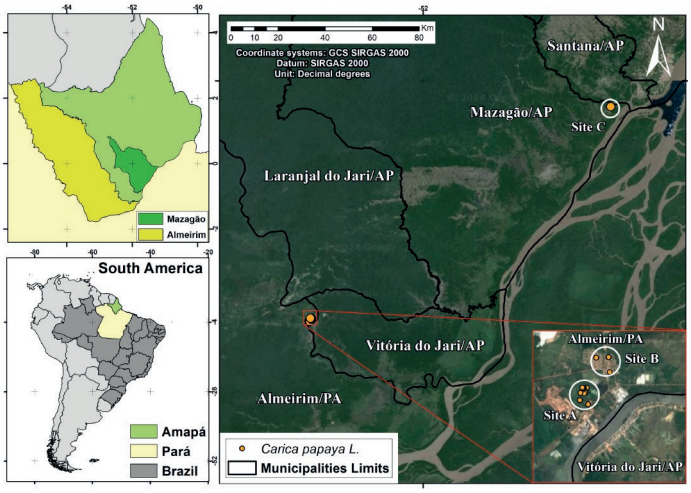

Figure 1. Location map of the *Carica papaya* fruit sampling points in the states of Amapá and Pará, Brazil.

The sampled material was transported to the Plant Protection Laboratory at Embrapa Amapá, in Macapá (from Sites A and B) or to the Entomology Nucleus Laboratory at the Universidade Federal do Amapá, in Mazagão (from Site C). In the laboratory, the trays were covered with organza attached by elastic alloy and were kept for 28 days. Each seven days, the samples were examined to collect puparia. To avoid desiccation of the puparia, humidity was maintained in the trays by replacing water with the help of a spray bottle. The puparia obtained from each sample were stored in plastic containers (8 cm in diameter) which contained a thin layer of moistened vermiculite. The plastic containers were covered with organza and a vented lid, being inspected daily. The fruit flies that emerged were stored in glass vials containing 70% etanol, for later identification. The identification of CFF was based on Zucchi (2000) and Plant Health Australia (2018). Voucher specimens were deposited at the Plant Protection Laboratory

of Embrapa Amapá, in Macapá, Amapá.

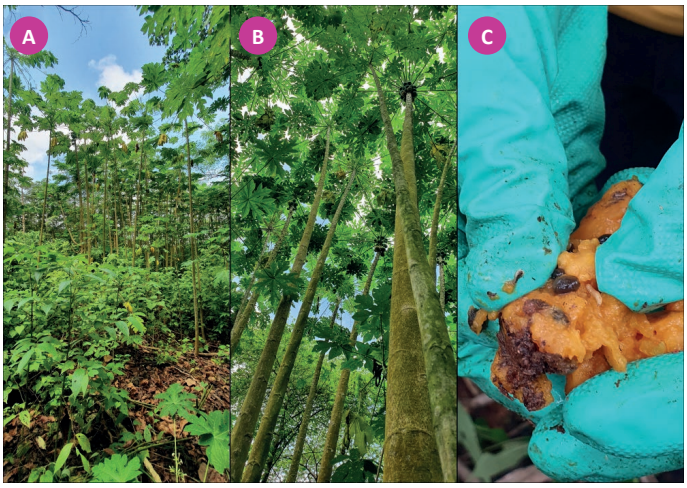

Figure 2. *Carica papaya* plants found on Site A (private area of the company Jari Celulose S.A., Monte Dourado District, municipality of Almeirim, state of Pará, Brazil). (A) General view of the area; (B) Visualization of the fruits; (C) Dissected fruit, showing the presence of larvae.

We did the following calculations: (I) infestation index = (number of puparia obtained in the sample ÷ sample mass in kilograms), expressed as the number of puparia per kg; (II) emergence percentage [(number of adults emerged ÷ number of puparia obtained in the sample) × 100].

We collected 16 samples of *C. papaya* (12 at Site A, 3 at Site B and 1 at Site C), totaling 117 fruits and 40.27 kg (Tab. 1). Fruit fly infestation was recorded in seven of the 16 samples collected (43.7%), with six samples at Site A and 1 at Site C. The infested samples had an average of 0.3-9.4 puparia/kg on Site A and 5.6 puparia/kg on Site C. In total, we obtained 102 fruit fly puparia, which gave rise to 64 specimens of CFF (29 females e 35 males). The average emergence was 62.7%, but in three samples it reached 100%. The data obtained in this study represents the first report of infestation of *C. papaya* fruits by CFF under natural conditions in Brazil and South America as well. It is noteworthy that the sites where we collected fruits of *C. papaya* infested by CFF in the states of Pará and Amapá are located very far from the largest producing regions in of this species in Brazil as we can see in Fig. 3. Also, the fruits sampled in this work (Fig. 4) do not have a defined cultivar and are morphologically different from the fruits of the Solo and Formosa groups, the most produced in Brazil (SEAG 2024).

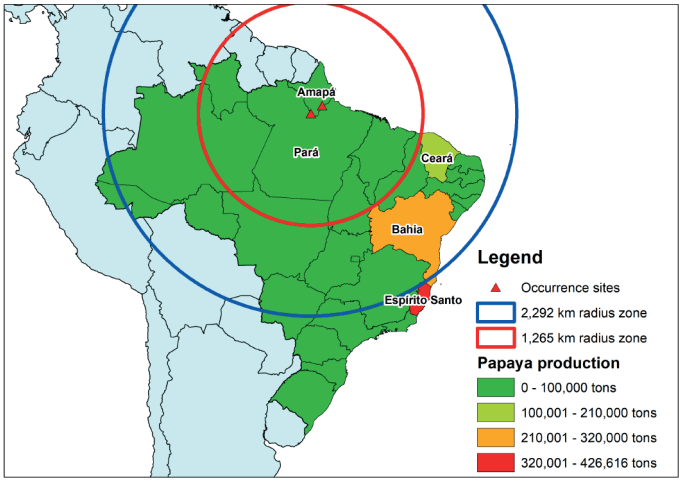

Figure 3. Estimated distance from the sites where *C. papaya* fruits were sampled (municipalities of Almeirim, state of Pará, and Mazagão, state of Amapá) to the largest producing regions in Brazil.

While infestation of *C. papaya* by fruit fly larvae is not a common occurrence, three species of fruit flies have been recorded infesting papaya in Brazil: *Anastrepha fraterculus* (Wiedemann, 1830) (Diptera: Tephritidae) in the Espírito Santo State; *Anastrepha striata* Schiner, 1868 in the Amapá State, and *Ceratitis capitata* (Wiedemann, 1824) (Diptera: Tephritidae) in the Espírito Santo, Bahia and Minas Gerais States (Martins & Alves 1988; Martins et al. 1993; Alvarenga et al. 2007; Leite et al. 2017; Costa et al. 2022).

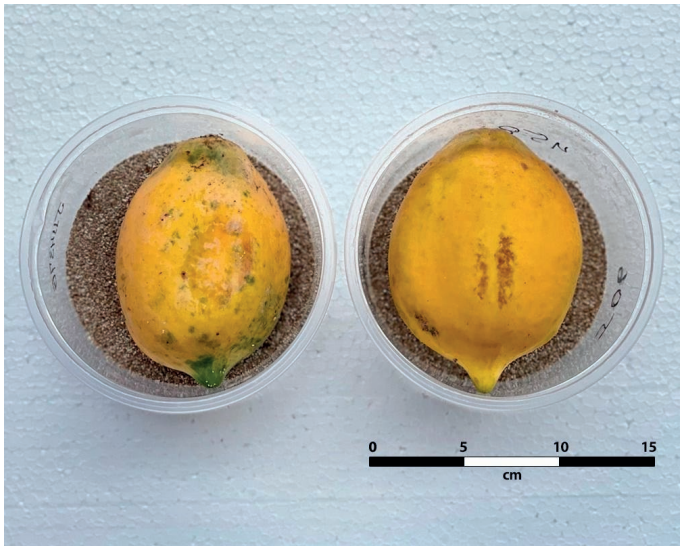

Figure 4. Fruits of *Carica papaya* sampled in the municipalities of Almeirim (state of Pará) and Mazagão (state of Amapá), Brazil.

On the other hand, the host condition of *C. papaya* for CFF remains a topic of debate in the literature, as there are few reports of its natural occurrence in field conditions. The first report of papaya as a host of CFF in the world was documented by Ranganath et al. (1997). The authors reported that the species was found on three occasions infesting the crop in the backyard of a residential complex in the south of Andaman, an island belonging to India. However, they did not document the ripeness stage of the fruit or the number of infested fruits.

In South America, it is important to highlight the work of van Sauers-Muller (2005) in Suriname, who collected 50 samples of papaya, totaling 137 fruits (33.10 kg), in natural environments over a period of 12 years and obtained only four puparia with no fruit flies emerging. Similarly, in French Guiana, Vayssières et al. (2013), recorded 14 host plant species of CFF in samples collected in the field between 2001 and 2003, obtaining in *C. papaya*, only *A. striata*, at a low infestation. In Brazil, papaya has rarely been sampled (only 28 samples, 147 fruits) in areas where the pest occurs and has never been infested (Adaime et al. 2017; Lemos et al. 2017; Costa et al. 2022; Costa et al. 2023a).

Papaya is considered a secondary host for fruit flies due to the presence of benzyl isothiocyanate (BITC) in the latex of the still "green" fruit. This chemical compound is responsible for the fruit's resistance to the insect, due to its ovicidal and oviposition-inhibiting action, which decreases as the fruit ripens (Seo & Tang 1982; Branco et al. 2000). Seo et al. (1983) noted that the natural oviposition tendency of *Bactrocera dorsalis* (Hendel, 1912), *C. capitata*, and *Bactrocera cucurbitae* (Coquilleu, 1899) is inhibited by BITC. Their results show there was an average percentage reduction to 57.7%, 93.3%, and 93.6% at a concentration of 1.9×10^{-10} mol/L by the three species, respectively. It was also observed that the number of *B. dorsalis* larvae per papaya fruit varied directly with ripeness (Seo et al. 1983). The low infestation by *B. carambolae* may be due to the natural resistance that the fruit seems to have due to the secretion of latex. A similar fact was observed by Unahawutti et al. (2014), who suggested that the natural infestation of *Garcinia mangostana* L. (Clusiaceae), a latex-containing fruit, can only occur if the fruit has physical cracks or mechanical damage.

Dias et al. (2018), in their analysis of the oviposition patterns in fruits of various plant species by two fruit fly species, identified a lower rate of aculeus insertion for *C. capitata* in papaya when compared to mango, relating this fact to the presence of BITC in the fruit. This substance is present in high concentrations in unripe papaya and decreases as the fruit ripens, suggesting that only ripe fruit is infested in the field (Seo et al. 1983). These data indicate that *C. capitata* may be less affected by BITC (Dias et al. 2018), a fact corroborated by Joachim-Bravo & Silva-Neto (2004), who reported a preference of *C. capitata* for papaya, followed by mango and orange.

Table 1. Species of fruit flies obtained from fruit samples of *Carica papaya*, in Monte Dourado District/Almeirim/Pará/Brazil and Mazagão/Amapá/Brazil.

Sample no.	Sites*	Coordinates		Dates	Fruits (n)	Mass (kg)	Puparia (n)	*Bactrocera carambolae*		Infestation (PP/kg)	Emergence (%)
		Latidute S	Longitude W					Female	Male		
1	A	-0.9160	-52.4341	02/28/2022	2	0.88	0	0	0	0.0	-
2	A	-0.9149	-52.4340	02/28/2022	3	1.19	0	0	0	0.0	-
3	A	-0.9148	-52.4341	02/28/2022	8	3.50	18	6	8	5.1	77.8
4	A	-0.9148	-52.4330	03/10/2022	7	3.85	5	0	0	1.3	0.0
5	A	-0.9149	-52.4337	03/10/2022	11	2.92	1	1	0	0.3	100.0
6	A	-0.9149	-52.4340	03/10/2022	19	4.84	3	0	0	0.6	0.0
7	A	-0.9147	-52.4342	03/10/2022	15	5.70	0	0	0	0.0	-
8	A	-0.9160	-52.4334	03/10/2022	6	2.05	0	0	0	0.0	-
9	A	-0.9163	-52.4338	03/10/2022	17	6.29	59	15	18	9.4	55.9
10	A	-0.9161	-52.4347	03/10/2022	6	1.98	0	0	0	0.0	-
11	A	-0.9180	-52.4348	03/10/2022	7	3.39	9	4	5	2.7	100.0
12	A	-0.9191	-52.4327	03/10/2022	2	0.63	0	0	0	0.0	-
13	B	-0.9108	-52.4272	03/10/2022	2	0.48	0	0	0	0.0	-
14	B	-0.9069	-52.4274	03/10/2022	2	0.61	0	0	0	0.0	-
15	B	-0.9071	-52.4306	03/10/2022	2	0.71	0	0	0	0.0	-
16	C	-0.0986	-51.2825	03/19/2024	8	1.25	7	3	4	5.6	100.0

*Site A (private area of the company Jari Celulose S.A., Monte Dourado District, municipality of Almeirim, state of Pará): plants of *C. papaya* grew spontaneously; Site B (village of Munguba, Monte Dourado District, municipality of Almeirim, state of Pará): single plants in the urban area; and Site C (municipality of Mazagão, state of Amapá): single plant in the urban area.

Furthermore, as reported by Martins & Alves (1988), the highest infestations of *C. capitata* in papayas are typically observed in areas with a consistent presence of overripe fruit and an abundance of discarded fruit. In this study, in the area where the papaya was collected, several fallen fruits could be seen on the ground, which may have influenced the occurrence, albeit minimally, to the infestation by CFF.

In view of the above, it is important to recognize that the papaya crop can be considered a secondary (non-preferential) natural host of CFF since the fruit apparently has a natural resistance to attack when still "green," due to the presence of BITC. Furthermore, for the purposes of importing papaya from Brazil, the USA considers *C. papaya* to be a non-preferred host of *B. carambolae* (USDA 2022). A host plant preference study carried out under laboratory conditions in Indonesia indicated that *C. papaya* is a non-preferred host fruit for CFF (Koswanudin et al. 2018).

Given the quarantine status of CFF for Brazilian fruit production, it is imperative to carry out more research, together with strict agricultural defense actions, to minimize the risks of the pest going beyond the geographic domains in which it is currently present and reaching papaya production areas of the country.

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Authors' Contributions

JVTAC: Conceptualization, Investigation, Methodology, Writing - original draft; MSMS: Investigation, Methodology, Writing - review and editing; MFSF: Investigation, Writing - review and editing; LNL: Investigation; EVP: Investigation; DEN: Conceptualization, Writing - original draft, Writing - review and editing; RA: Conceptualization, Methodology, Writing - original draft, Writing - review and editing, Supervision.

Conflict of Interest Statement

The authors declare no competing interests.

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