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Occurrence of *Anastrepha fraterculus* and *Ceratitis capitata* (Diptera: Tephritidae) in organically grown *Rubus* (Rosales: Rosaceae), in two contrasting environments of northwestern Argentina

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The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), and the South American fruit fly, *Anastrepha fraterculus* (Wiedemann) (Diptera: Tephritidae), are widely distributed in Argentina, including the northwestern province of Tucumán (Segura et al. 2006; Guillén & Sánchez 2007; Ovruski et al. 2010). Tucumán is one of the most important berry-exporting regions of the country (Kirschbaum 2011). In Tucumán, the presence of fruit flies, especially *C. capitata*, determines methyl bromide treatments to fresh blueberries exported to the United States (Pérez & Mazzone 2012). In recent years, researchers, fruit growers, and consumers have been increasingly interested in small fruits such as blackberries (*Rubus fruticosus* L.; Rosaceae) and raspberries (*Rubus idaeus* L.; Rosaceae) because of their content of basic nutrients, fiber, vitamins, and phenolic compounds (Ancos et al. 2000; Harborne & Williams 2000; Souza et al. 2014). Additionally, they are considered a good alternative crop for small-scale growers because of low production costs and relatively low levels of susceptibility to pests and diseases (Hussain et al. 2016).

In Tucumán, berries are grown in 2 contrasting regions: the humid piedmont and the semiarid intermontane valley of Tafi (Zuccardi & Fadda 1985; del Río et al. 2010). In the humid piedmont, the mesoclimate is wet and warm, with annual rainfall >1,000 mm (concentrated in the summer) and potential evapotranspiration about 900 mm. It is a frost-free region, although frosts can occur occasionally. In the intermontane valley of Tafi, the mesoclimate is temperate semiarid, with about 400 mm annual precipitation (concentrated in the summer), 500 to 600 mm evapotranspiration and a 7 mo frost period (Zuccardi & Fadda 1985). Given that raspberry and blackberry are minor (but expanding) crops in Tucumán, information about their phytosanitary aspects is scarce and fragmented (Reguilón et al. 2015), and they were not included in previous local studies as possible fruit fly host plants. In this context, the purpose of this study was to determine the occurrence of *A. fraterculus* and *C. capitata* in organic *Rubus* crops grown in these 2 very contrasting environments of northwestern Argentina.

During 2 production seasons, 2013 and 2014, ripe fruit (stage III, according to Bisognin et al. 2015) from plants of 3 blackberry cultivars (878, Navaho, and Tupi) were collected from an organic orchard in Monte Grande (27.0000°S, 65.4000°W; 350 m altitude), at the depart-

ment of Famaillá (Tucumán Province, Argentina), in the humid piedmont (Zuccardi & Fadda 1985). In addition, in 2016 ripe fruit samples of the blackberry cultivar 878 and the raspberry cultivar Heritage were collected from an organic farm in Tafi del Valle (26.8666°S, 65.6833°W; 1,900 m altitude), another department of Tucumán Province, in the intermontane semiarid valleys (Zuccardi & Fadda 1985). No pesticides were applied.

Rubus crops are harvested in spring (Nov–Dec) and summer (Jan–Mar) in Monte Grande and Tafi del Valle, respectively. Consequently, sampling dates in Monte Grande were 6, 14, and 20 Nov, 5 and 13 Dec 2013, and 7, 12, and 19 Nov 2014; and those in Tafi del Valle were 5, 19, and 24 Feb, and 10 and 23 Mar 2016.

Each fruit sample was individually packaged and taken to the laboratory, divided into 2 replicates of 20 to 30 fruits each, and placed into plastic containers (20 × 30 cm) with sand at the bottom for larval pupation. The lids of the containers were removed and replaced by voile fabric to allow air exchange and to prevent insects from escaping. The containers were kept at about 25 °C and 60 to 70% RH for 20 d. Tephritid adults from each clamshell were recovered weekly, identified (Zucchi 2000), and counted. The reported fruit infestation level was based on the number of fruit fly adults per fruit and kg of fruit. Precipitation (P) and evapotranspiration (ET) data were obtained from a weather station located nearby Monte Grande. The hydric balance (HB) was calculated by subtracting ET from P (HB = P – ET).

Annual precipitation varied from 2013 to 2014. The first can be considered a dry year (low precipitation and 8 mo with negative HB), whereas 2014 could be described as a humid year (high precipitation and 4 mo of negative HB) (Fig. 1).

The total weight and number of analyzed fruit in 2013 and 2014 are shown in Table 1. In 2013, the occurrence of fruit flies was observed only on the last sampling date, 13 Dec. *Ceratitis capitata* pupae were recorded in fruit samples of the blackberry cultivars 878 (3 pupae) and Tupi (3 pupae); adults of *A. fraterculus* emerged from fruits of Tupi (2 adults). This is the first report of the occurrence of *A. fraterculus* and *C. capitata* on blackberries in northwestern Argentina, although with low infestation levels (Table 1). In 2014, *A. fraterculus* was observed in 878 and Tupi, whereas *C. capitata* ap-

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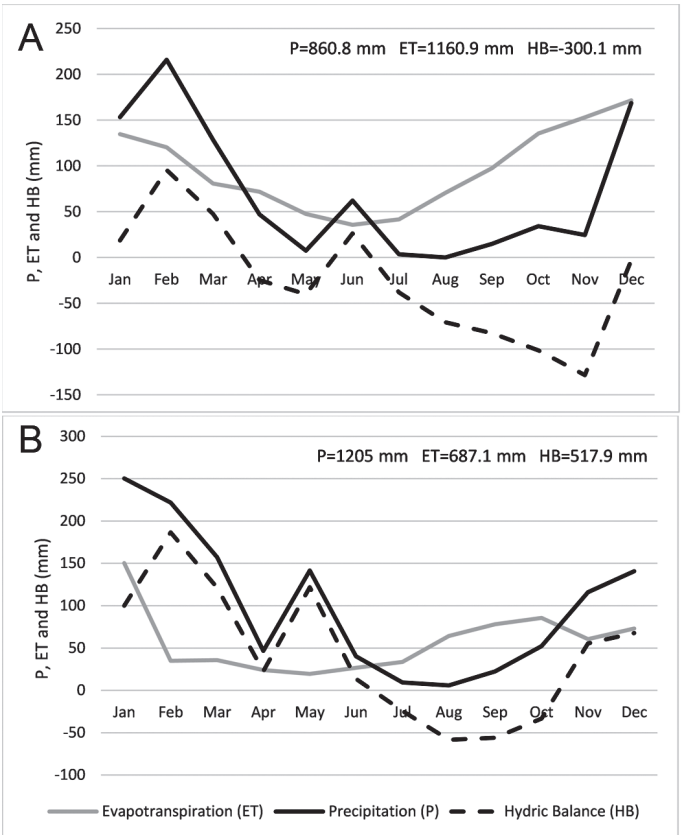


Fig. 1. Precipitation (P), evapotranspiration (ET), and hydric balance (HB = P – ET) near Monte Grande (27.0000°S, 65.4000°W; 350 m altitude; Tucumán, Argentina) in 2013 (A) and 2014 (B).

peared only in Tupi, at higher infestation levels than in 2013 (Table 1). During this study, no fruit fly was recorded from Navaho blackberries.

The total weight and number of analyzed fruit in 2016 are shown in Table 1. Pupae and adults of *A. fraterculus* were observed in blackberry (878) and raspberry (Heritage) fruit samples along the monitoring period, although this insect was not present in blackberry on the last sampling date. No individual of *C. capitata* was recorded during this study. In total, 144 adults and 23 pupae of *A.*

fraterculus were found in raspberry, whereas in blackberry only 29 adults and 4 pupae were recovered. This is the first report of the occurrence of fruit flies in raspberry fruits in northwestern Argentina, and with high infestation levels (Table 1). Infestation levels of *A. fraterculus* varied considerably between host plant species within the genus *Rubus* (Table 1). Raspberries were infested more than blackberries. Infestation levels in raspberries were 2.4 and 6.1 times higher than in blackberries, in terms of fruit flies per kg and fruit flies per fruit, respectively.

It is known that for tephritids, in general, first rains stimulate adult emergence from overwintering pupae in the soil, causing fruit flies to become active after periods of relatively high humidity (Bateman 1972). Therefore, rain, soil water content, and air RH may have been involved in the determination of the time of fruit fly emergence in the present study. However, fruit fly abundance should be tracked for several more years for confirmation. In 2014, *A. fraterculus* was nearly twice as abundant as *C. capitata*. The absence of *C. capitata* in Tafí del Valle might be related to climatic and host-related issues (Duyck et al. 2006; Ovruski et al. 2010; Flores et al. 2016).

Future research should include monitoring of fruit flies in neighbor fruit plants, occurrence of natural enemies, and fruit fly preference for blackberry varieties. These monitoring tools will be useful for improving organic berry production.

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Summary

In Tucumán (northwestern Argentina) during 2013 and 2014, *Anastrepha fraterculus* (Wiedemann) (Diptera: Tephritidae) and *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) were found infesting organically grown blackberries in the humid piedmont region (Monte Grande, Famaillá). In 2016, only *A. fraterculus* was found infesting organically grown blackberries and raspberries in

Table 1. Total fruit weight, total fruit number, number of fruit flies, and infestation levels (number of fruit flies per fruit and per fruit weight) of *Anastrepha fraterculus* and *Ceratitis capitata* in blackberry cultivars organically grown in Monte Grande (27.0000°S, 65.4000°W; 350 m altitude); and in blackberry and raspberry cultivars organically grown in Tafí del Valle (26.8666°S, 65.6833°W; 1,900 m altitude), Tucumán, Argentina.

Location and year	Rubus species and cultivar	Total fruit weight (kg)	Total fruit number	A. fraterculus			C. capitata		
				Nff ^a	Nff per kg of fruit	Nff per fruit	Nff	Nff per kg of fruit	Nff per fruit
Monte Grande									
2013	Blackberry 878	2.81	454	0	0	0	3	1.07	0.007
	Blackberry Tupi	2.08	389	2	0.96	0.005	3	1.44	0.008
	Blackberry Navaho	2.69	737	0	0	0	0	0	0
2014	Blackberry 878	1.41	267	11	7.80	0.041	6	4.26	0.023
	Blackberry Tupi	1.51	312	24	15.86	0.077	13	8.59	0.042
	Blackberry Navaho	1.38	414	0	0	0	0	0	0
Tafi del Valle									
2016	Blackberry 878	0.73	102	33	45.30	0.324	0	0	0
	Raspberry Heritage	0.60	214	167	278.70	0.780	0	0	0

^aNff: number of fruit flies.

the temperate semiarid region (Tafí del Valle), where studies conducted in prior years showed coexistence of both fruit fly species with prevalence of *C. capitata* over *A. fraterculus*, but in other fruit species. In this study, we found that *A. fraterculus* had a remarkable preference for raspberries over blackberries. These are the first records of fruit fly occurrence in *Rubus* (Rosales: Rosaceae) in northwestern Argentina and expand the range of host species for fruit flies in the region. Fruit fly infestation levels in blackberries in the humid region were very low, whereas fruit fly infestation in the semiarid region was relatively high. Based on our observations, we hypothesize that spring rains, soil moisture, and relative humidity determine the time of appearance of fruit flies in blackberries in the humid region. Fruit fly abundance should be tracked for several more years to test this hypothesis. In addition, fruit flies were not recovered from fruit samples of the blackberry cultivar Navaho, which is interesting from both an agronomic and scientific perspective.

Key Words: fruit fly; blackberry; raspberry; host preference; Tucumán

Sumario

En Tucumán (noroeste de Argentina,) durante 2013 y 2014 se encontraron *Anastrepha fraterculus* (Wiedemann) (Diptera: Tephritidae) y *Ceratitidis capitata* (Wiedemann) (Diptera: Tephritidae) infestando zarzamoras orgánicas en la región del pedemonte húmedo (Monte Grande, Famaillá). En 2016, sólo se encontró *A. fraterculus* infestando zarzamoras y frambuesas orgánicas en la región templada semiárida (Tafí del Valle), donde estudios realizados en años anteriores mostraron la coexistencia de ambas especies de mosca de la fruta con prevalencia de *C. capitata* sobre *A. fraterculus*, pero en otras especies frutales. Cabe señalar que en este estudio, encontramos que *A. fraterculus* tenía una notable preferencia por las frambuesas sobre las moras. Estos son los primeros registros de ocurrencia de moscas de la fruta en *Rubus* (Rosales: Rosaceae) en el noroeste de Argentina y amplían el rango de especies hospedantes para las moscas de la fruta en la región. Los niveles de infestación en moras en la región húmeda fueron muy bajos, mientras que en la región semiárida fueron relativamente altos. Sobre la base de nuestras observaciones, hipotetizamos que las lluvias de primavera, la humedad del suelo y la humedad relativa determinan el momento de aparición de las moscas de la fruta en moras en la región húmeda. La abundancia de la mosca de la fruta se debería seguir durante varios años más para probar esta hipótesis. Además, las moscas de la fruta no se recuperaron de las muestras de fruta de la variedad de zarzamora Navaho, lo cual es interesante desde una perspectiva agronómica y científica.

Palabras Clave: mosca de la fruta; mora; frambuesa; preferencia de hospedero; Tucumán

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