

Comparison of Food Attractants for Monitoring Fruit Fly (*Diptera: Tephritidae*) in Citrus Orchards in Brazil

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Abstract

Anastrepha fraterculus (Wiedemann) and *Ceratitidis capitata* (Wiedemann) are the most important fruit fly species in Brazil. Both species causes significant losses in citrus production in the State of São Paulo. The aim of this study was to compare the efficacy of different food bait attractants for monitoring fruit flies in Integrated Pest Management (IPM) programs. The experiment was conducted under block randomized design with seven attractants (BioAnastrepha, IscaMosca, Samaritá, Torula[®], Milhocina[®] plus borax, sugar cane molasses and grape juice). The experiments were performed in two seasons, from March until April (season 1) and from November until December 2008 (season 2), in two orange orchards (organic and conventional systems) located in Mogi-Guaçu, SP. The number of flies captured by each attractant was evaluated weekly during seven weeks. In total 4,327 adults of Tephritidae were captured: 3,073 specimens of *A. fraterculus* and 1,258 specimens of *C. capitata*. Milhocina[®] plus borax and Torula[®] during season 1, and Torula[®] during season 2 were more effective to capture fruit flies. In organic orchard, Torula[®] and BioAnastrepha captured significantly more tephritids during season 2. In general, Torula[®] attracted more females than males.

Keywords: *Ceratitidis capitata*, *Anastrepha fraterculus*, monitoring, McPhail trap

INTRODUCTION

The State of Sao Paulo is the largest orange fruit exporter and producer in Brazil, with about 570,000 ha (CONAB, 2011). Among the main citrus problems in the region, fruit flies (*Diptera: Tephritidae*) are considered key pests because they compromise the consumption of fresh fruit and restrict trade through phytosanitary under quarantine barriers (Malavasi et al., 2000; Raga, 2005).

Due to the high capacity of dispersion and adaptation, fruit flies are widely distributed in almost all continents and are harmful to fruit crops. The management of tephritids depends essentially of adult monitoring in the orchard (Scoz et al., 2006). The population fluctuation of fruit flies varies from year to year and is directly related to climate and availability of hosts (Aluja, 1994; Souza Filho et al., 2003; Raga, 2005). In Sao Paulo State there is a great diversity of fruit fly hosts, enabling the survival and population growth during all year long (Orlando and Sampaio, 1973). The most important species to the citrus in Sao Paulo are the South American fruit fly *Anastrepha fraterculus* (Wiedemann, 1830) and the medfly *Ceratitidis capitata* (Wiedemann, 1824) (Raga et al., 2004).

McPhail traps are used to monitoring fruit fly with food baits (Morgante, 1991; Aluja, 1994). The selection of the right food attractant is crucial to estimate the fruit fly population for further the decision-making in IPM programs (Raga, 2005). According to Robacker et al. (1991), both the protein and the sugar are essential to fruit flies, being the first necessary for the maturation of the gonads and the second for energy. The objectives

of this study were to compare the efficiency of different food bait attractants in capturing fruit flies and to determine their seasonal fluctuation in two commercial citrus orchards.

MATERIALS AND METHODS

The study was performed in two seasons of the year using orange citrus (*Citrus sinensis*) orchards conducted under two production systems: conventional and organic. The orchards were four kilometers away from each other and they were located in Yamaguishi Farm (22°08'35.75" S; 47°09'42.21" O; 627.9 m), municipality of Mogi-Guaçu, State of São Paulo, Brazil. Cultural practices were provided by the grower according to the specific schedule of each production system.

During season one, from 03/10/2008 to 04/28/2008, the organic orchard was formed by 'Pera' with an area of 6.36 ha and each plot had 1,764 m². The conventional orchard was formed by 'Hamlin' with an area of 14.98 ha and each plot had 2,304 m². During season two, from 11/10/2008 to 12/29/2008, both orchards were 'Pera'. The organic orchard had an area of a 7.98 ha and each plot 1,260 m², while in the conventional orchard each plot had 1,525 m² distributed in an area of 14.16 ha.

Every McPhail trap was filled with 400 ml of the diluted attractant. The treatments were: BioAnastreha (3% v/v), Isca Mosca (3% v/v), Samaritá (3% v/v), Torula[®] (3 tablets per trap), Milhocina[®] plus borax (5% v/v +3% p/v), sugar cane molasses (7% v/v) and grape juice Aurora brand (25% v/v). The attractive Torula[®] was chosen as a standard for presenting the best performance in capturing among different *Anastrepha* species in different hosts (Lopez et al., 1971; Hedström and Jirón, 1985), as well as for medfly (Jirón and Soto-Manitiu, 1989).

We adopted randomized block design with seven treatments and four replications. During each season the experiment was conducted during eight weeks and the captures were evaluated weekly. *Anastrepha* females were identified according to the key provided by Zucchi (2000). Population fluctuation was measured by FTD (flies/trap/day). Data were transformed to log (x+5) and compared by Tukey's test (p<0,05) using the softwear AgroEstat version 1.0 (2008).

RESULTS AND DISCUSSION

Tephritids Captured

A total of 4,327 Tephritidae adults were captured during both seasons. In the first season, from 508 adults of fruit flies, were captured 284 specimens in the organic orchard and 224 specimens in the conventional orchard. In the second season we capture 3,819 adults of tephritids, with 3,603 specimens in organic orchard and 216 specimens in the conventional orchard. The ratio was 1.00:0.75 (1,755 females and 1,318 males) and 1.00:0.41 (891 females and 363 males) for *Anastrepha* spp. and *C. capitata*, respectively. Generally, traps containing food baits capture more females than males of tephritids (Robacker, 1991).

Anastrepha specimens represented 71.02% (3,073 specimens) of tephritids captured while *C. capitata* reached 28.98% (1,254 specimens). This proportion was similar to that obtained in citrus orchards in the western state of Santa Catarina (Chiaradia et al., 2004), Belmonte city (state of Bahia) (Santos et al., 2011) and 25 cities of the state of São Paulo (Raga et al., 2004). A reversal of higher incidence of the Medfly with South American fruit fly in citrus groves in the state of São Paulo may be changing due to intense urbanization in orange producing regions (Raga et al., 2004).

Among the *Anastrepha* females captured, *A. fraterculus* was dominant, with 1,752 individuals, followed by *A. sororcula* with two individuals and *A. distincta* Greene with just one individual. Therefore, we considered only *A. fraterculus* for statistical analysis because the remainder collected species were not related to citrus fruit in Brazil (Raga et al., 2004; Raga, 2005).

Comparison of Food Attractants

During both seasons of the trial, there were differences in performance of the attractive in both production systems (Table 1). In conventional orchard, during the first season of the study, the attractive solution Milhocina[®] plus borax captured significantly more males of *A. fraterculus* than BioAnastrepha, not differing from other attractive solutions. Milhocina[®] plus borax and Torula[®] were significantly more efficient than others attractants in capturing females plus males and only females of the medfly. There was no statistical difference between the capture values of females and females plus males of the South American fruit fly. In this same season in the organic orchard, attractive solutions did not differ in relation to the capture of *A. fraterculus* and no specimens of *C. capitata* was detected (Table 1).

During the second season in the conventional orchard, Torula[®] captured significantly more females and males plus females of *C. capitata* than remainder attractive solutions, while the capture values for males of this species didn't differ significantly from BioAnastrepha, IscaMosca, Milhocina[®] plus borax and grape juice. Torula[®] captured significantly more *A. fraterculus* females than the others attractants, and the number of females and males captured by this attractive differed statistically only from IscaMosca. The capture of *A. fraterculus* males were similar among the treatments (Table 2).

During the second season of the organic orchard, Torula[®] and BioAnastrepha caught significantly more females and females plus males of *A. fraterculus* and *C. capitata* than remainder attractants. Torula[®] was more efficient than BioAnastrepha and sugar cane molasses was less efficient than the remainder attractants ($p < 0.05$). For *A. fraterculus* and *C. capitata* males the amount of capture by Torula[®] was significantly higher compared to the other treatments (Table 2).

Milhocina[®] added borax to 3%, when compared to standard Torula[®] and the commercial attractant BioAnastrepha and Isca Mosca, exhibited good performance, especially during the first season (Tables 1 and 2). According to Soto-Manitui (1989), hydrolyzed protein solution with the addition of borax significantly was more effective in capturing adults of *A. fraterculus* than Torula[®] in a guava orchard in Costa Rica.

Samaritá, grape juice and sugar cane molasses showed lower captures (Tables 1 and 2). The low efficiency of these components in the attractiveness of fruit flies has been reported in earlier similar study (Raga et al., 1996; Raga et al., 2006). However, fruit juice and molasses are used for monitoring the attractions for some fruit growers due to its low cost (Raga et al., 2006), compromising the monitoring results and the decision-making.

Table 1. Comparison of food attractants for capturing females (F) and males (M) of *Ceratitidis capitata* (Cc) and *Anastrepha fraterculus* (Af) in conventional and organic citrus orchards. Mogi-Guaçu, SP, Brazil, during season one (from 03/17/2008 to 04/28/2008).

Season 1 Treatment	Conventional system						Organic system		
	Af F	Af M	Af F+M	Cc F	Cc M	Cc F+M	Af F	Af M	Af F+M
BioAnastrepha	0.71a	0.70b	0.72a	0.70b	0.70a	0.71ab	0.74a	0.73a	0.77a
Isca Mosca	0.73a	0.72ab	0.75a	0.69b	0.70a	0.70b	0.71a	0.71a	0.73a
Samaritá	0.71a	0.71ab	0.73a	0.69b	0.70a	0.70b	0.74a	0.75a	0.77a
Torula	0.77a	0.74ab	0.81a	0.72a	0.70a	0.72a	0.78a	0.75a	0.82a
Milhocina + bórax	0.77a	0.78a	0.83a	0.72a	0.70a	0.72a	0.74a	0.73a	0.76a
Molasse Sugarcane	0.71a	0.70ab	0.71a	0.69b	0.69a	0.69b	0.73a	0.74a	0.76a
Grapejuice	0.73a	0.72ab	0.76a	0.69b	0.69a	0.69b	0.75a	0.73a	0.77a
General average	0.74	0.72	0.76	0.70	0.70	0.71	0.74	0.73	0.77
LSD (5%)	0.08	0.08	0.12	0.02	0.10	0.02	0.08	0.08	0.12
CV (%)	11.86	12.22	17.38	3.01	1.97	3.66	12.17	12.94	18.22

Data followed by the same letter in the same column do not differ significantly according to Tukey's HSD test ($p > 0.05$).

Table 2. Comparison of food attractants for capturing females (F) and males (M) of *Ceratitidis capitata* (Cc) and *Anastrepha fraterculus* (Af) in conventional and organic citrus orchards. Mogi-Guaçu, SP, Brazil, during season two (from 11/17/2008 to 12/29/2008).

Season 2 Treatment	Conventional system						Organic system					
	Af F	Af M	Af F+M	Cc F	Cc M	Cc F+M	Af F	Af M	Af F+M	Cc F	Cc M	Cc F+M
BioAnastrepha	0.69b	0.70a	0.70ab	0.73b	0.71ab	0.74b	1.12b	0.99b	1.22b	0.94b	0.80b	1.00b
Isca Mosca	0.69b	0.69a	0.69b	0.72b	0.71ab	0.73b	0.96cd	0.95bc	1.09cd	0.88bc	0.77bc	0.92bc
Samaritá	0.69b	0.70a	0.70ab	0.70b	0.70b	0.70b	0.89de	0.87cd	0.98de	0.77de	0.72c	0.79de
Torula	0.72a	0.71a	0.73a	0.86a	0.74a	0.89a	1.27a	1.19a	1.39a	1.12a	0.93a	1.21a
Milhocina + bórax	0.70b	0.70a	0.71ab	0.75b	0.71ab	0.74b	1.01bc	0.96bc	1.12bc	0.85bcd	0.76bc	0.89bcd
Molasse Sugarcane	0.70b	0.70a	0.70ab	0.70b	0.70b	0.71b	0.83e	0.82d	0.92e	0.71e	0.71c	0.73e
Grapejuice	0.69b	0.70a	0.70ab	0.72b	0.71ab	0.72b	0.92cde	0.91bcd	1.03cde	0.80de	0.78bc	0.86cd
General average	0.70	0.70	0.70	0.74	0.71	0.75	1.00	0.96	1.11	0.87	0.78	0.91
LSD (5%)	0.01	0.02	0.03	0.06	0.04	0.08	0.10	0.11	0.12	0.09	0.07	0.11
CV (%)	2.56	3.50	5.28	9.75	6.85	12.02	12.17	13.44	12.39	12.81	10.56	14.37

Population Fluctuation

During the first season in the organic orchard curve fluctuation of *A. fraterculus* exhibited FTD values above 50.0 from 17 to 31 march 2008 and a declining population thereafter. In the conventional orchard the fluctuation curve of the South American fruit fly had a mean value of FTD around 5.0 with a decline of capturing in 03/31/2008. In conventional orchard captures of *C. capitata* ranged around 1.0 FTD. Studies conducted in two citrus orchards in western of the state of Santa Catarina (Brazil) also showed a high incidence of *A. fraterculus* and a low catching of medfly (Chiaradia et al., 2004).

In the second season, the population fluctuation of *A. fraterculus* in the organic orchard showed 93.1 as maximum value of FTD, whereas in the conventional orchard the maximum value was 8.9 FTD. For *C. capitata* the maximum FTD exhibited in the organic orchard was 42.4 and in the conventional orchard was 8.9. Seasonality is a characteristic of the population of *C. capitata* in the State of São Paulo (Souza Filho et al., 2009), with higher incidence in citrus orchards from late August to November, caused by the maturation of fruits occurred in dry period (Puzzi and Orlando, 1965; Raga et al., 1996). The increasing of the population of fruit flies occurred during the second season of the study that took place during the transition from spring to summer, along with high temperatures, with a greater supply of food and alternative hosts. The monitoring curves, representing the total number of flies captured, henceforth called total curve, exhibit differences from the curves represented by the capture of tephritid per attractive solution (Figs. 1 and 2). Although all attractants detected the presence of *A. fraterculus* in conventional orchard during phase 1, the population fluctuation presented by Milhocina[®] plus borax, Torula[®] and IscaMosca had the greatest similarity with the total curve, following the peaks and reduction of the fruit fly population. On 04/14/2008, Milhocina[®] plus borax had the highest peak with FTD of 3.3, followed by Torula[®] with FTD of 1.1.

In conventional orchard, during the first season of the study, the presence of *C. capitata* was not detected by the attractiveness molasses and grape juice. Torula[®] was the only attractant to present the fluctuation curve similar to the total curve, showing the same peaks rise and fall of the population fluctuation. The first peak presented by total curve on 03/24/2008 was also presented by the treatments Torula[®], with a FTD of 0.4, BioAnastrepha and IscaMosca, both with FTD of 0.1. The second peak of the total curve, on 04/07/2008, was presented by Milhocina[®] plus borax, Torula[®] and Samarita with, respectively, FTD values of 1.1, 0.4 and 0.1.

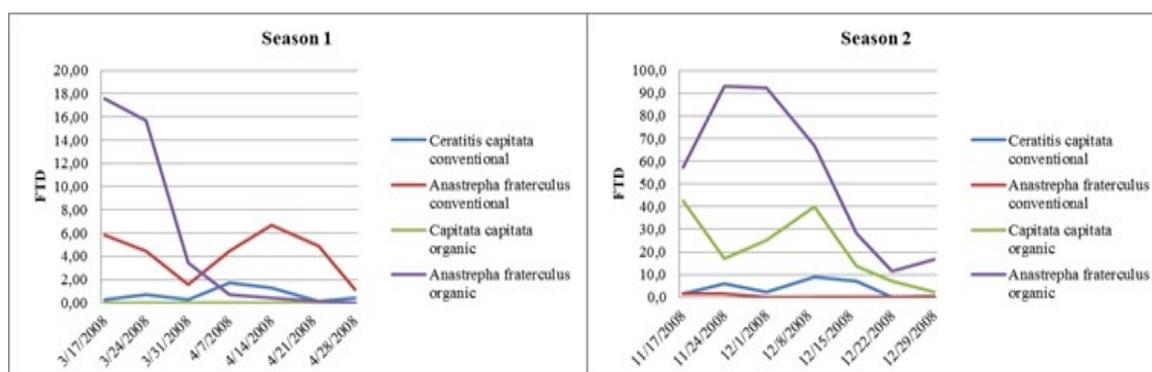


Fig. 1. Population fluctuation curve of fruit flies in organic and conventional orchards of orange in two seasons of the year, located in Mogi-Guaçu city, São Paulo, Brazil.

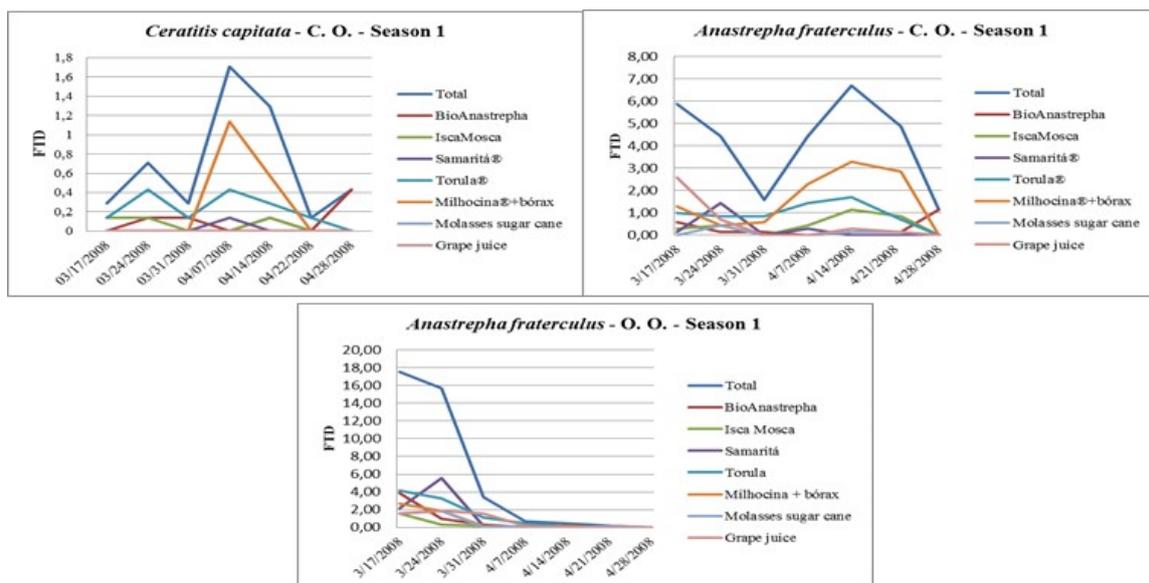


Fig. 2. Population fluctuation of *Ceratitis capitata* and *Anastrepha fraterculus* in conventional (C.O.) and organic (O.O.) orange orchards during season 1 (from 03/24/2008 to 04/28/2008), captured with different attractants.

During season one in the organic orchard, the population fluctuation of *A. fraterculus* had the highest peak on 03/17/2008 with a FTD index of 17.6, exhibiting a decline of flies caught during the following evaluations. Among of the treatments, curve provided by Torula[®] was the most similar to the total curve. The treatments fluctuation curves also had higher levels of FTD in the first evaluation (03/17/2008) followed by fall in capturing individuals, except Samaritá which showed the higher FTD on 03/24/08 (Fig. 3).

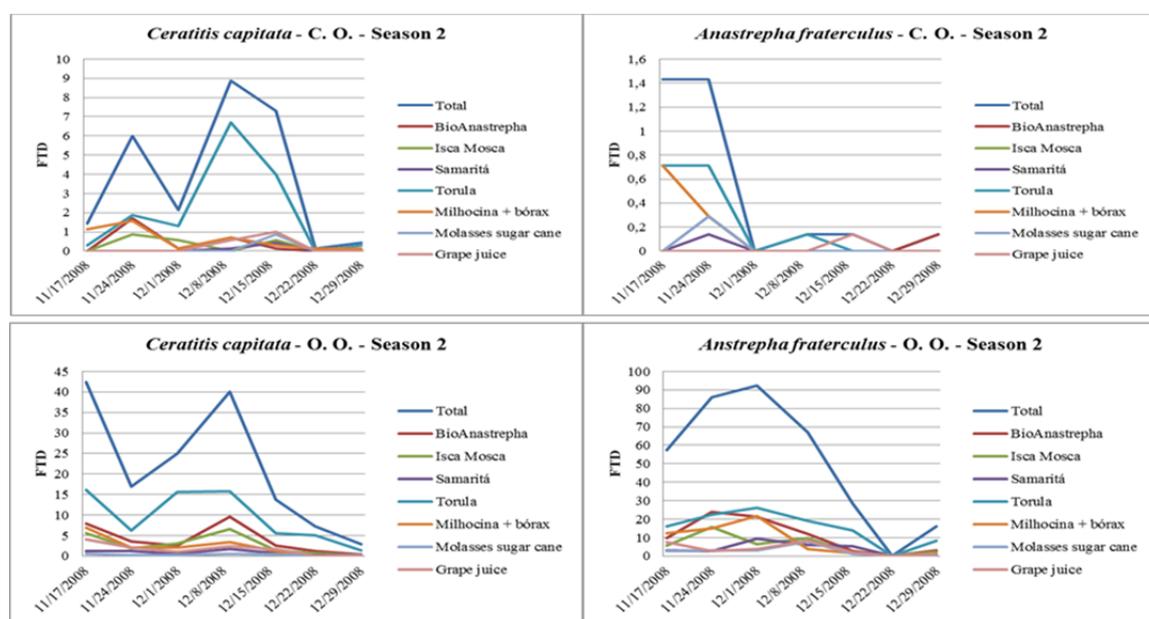


Fig. 3. Population fluctuation of *Ceratitis capitata* and *Anastrepha fraterculus* in conventional (C.O.) and organic (O.O.) orange orchards during season 2 (from 11/17/2008 to 12/29/2008) captured with different attractants.

The population fluctuation of *C. capitata* in conventional orchard during the second season presented peaks on 11/24/2008, 08 and 12/15/2008 with, respectively, FTD of 6.0, 8.9 and 7.3. Milhocina[®] plus borax had the fluctuation curve most similar to the total curve, with respective peaks in the same days and FTD of 1.9, 6.7 and 4.0. In the same orchard, the fluctuation of *A. fraterculus* showed two population peaks, with FTD of 1.4 on 17 and 11/24/2008. Torula[®] presented a curve similar to the curve total, with peak on 11/17/2008 with 0.7 FTD. Milhocina[®] plus borax presented two fluctuation peaks of fruit flies on 17 and 11/24/2008, while Samarita and molasses had peaks only on 11/24/2008. Grape juice presented peaks on 16 and BioAnastrepha on 12/29/2008. According to Raga et al. (1996), in winter and spring in São Paulo (from July to November) there are the biggest catches of the medfly, while during the respective months of summer and autumn (from February to April) the population decreases.

In the organic orchard, during season two, the fluctuation curve of *C. capitata* exhibits peaks on 11/17/2008 and 08/12/2008, with FTDs of 42.4 and 40.0, respectively. All the population curves presented by each treatment were similar to the total curve, but with different rates of FTD. Among the attractions, Torula[®] and BioAnastrepha showed the highest values of FTD. The population fluctuation of *A. fraterculus*, in the same orchard during the same season, had a fluctuation peak on 12/01/2008 (92.4 FTD) and 12/29/2008 (16.29 FTD). All attractive solutions captured *A. fraterculus*, but the fluctuation curves of BioAnastrepha and Milhocina[®] plus borax were the most similar to the total curve.

CONCLUSIONS

The food attractants showed different levels of captures and they detected *Anastrepha fraterculus* and *Ceratitis capitata* populations in different times in orange groves. McPhail traps with attractive food-based protein or sugar solutions, despite attracting both sexes, capture more females than males. The highest catch rates of fruit flies occurred during the second season, between November and December. During March, November and December occurred populational peaks of *A. fraterculus* in Mogi Guaçu (state of São Paulo, Brazil) while peaks of *C. capitata* occurred in April, November and December.

Milhocina[®] plus borax and Torula[®] showed similar results in terms of attractivity of *C. capitata* and *A. fraterculus*. Both attractants had higher specificity to Tephritidae in comparison with the remainder treatments.

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