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Hole diameters in pet bottles used for fruit fly capture

Mauricio Paulo Batistella Pasini[1*], Dionísio Link[4], Alessandro Dal'Col Lúcio[2] and Diniz Fronza[3]

[1]*Programa de Pós-graduação em Agronomia, Universidade Federal de Santa Maria, 97105-900, Camobi, Santa Maria, Rio Grande do Sul, Brazil.*
[2]*Departamento de Fitotecnia, Centro de Ciências Rurais, Universidade Federal de Santa Maria, Camobi, Santa Maria, Rio Grande do Sul, Brazil.*
[3]*Colégio Politécnico, Universidade Federal de Santa Maria, Camobi, Santa Maria, Rio Grande do Sul, Brazil.* [4]*In Memoriam.*
**Author for correspondence. E-mail: mauricio.pasini@gmail.com.*

ABSTRACT. Two experiments were conducted during the period from 31 January to 6 March 2012 in Santa Maria, Rio Grande do Sul State, Brazil to determine the efficiency of different hole diameters in PET trap bottles on pests in guava and persimmon orchards. In a randomised block design in a factorial scheme, we assessed the average number adults of *Anastrepha fraterculus*, *Ceratitis capitata* (Diptera: Tephitidae) and *Zaprionus indianus* (Diptera: Drosophilidae) infruits thatemerged in two situations (in the plant and on the soil); we also assessed the number of captured adults in trap bottlesunder two conditions, different hole diameters and different days after placement of the attractive solution. Smaller diameter sizescaptured more *A. fraterculus*, *C. capitata* and *Z. indianus*adults. The 1.0 cm diameter was the most efficient hole size in reducing the adult emergence of Tephritidae to *Z. indianus*, whereas the smallest diameter hole sizes, 0.6 and 0.8 cm, showed the highest efficiencies in controlling adult emergence in persimmon fruit and guava fruit.

Keywords: alternative control, *Anastrepha fraterculus*, *Ceratitis capitata*, *Zaprionus indianus*.

Diâmetros de furos em garrafas pet na captura de moscas das frutas

RESUMO. Com o objetivo de determinar a eficiência de diferentes diâmetros de furos em garrafas PET na captura de moscas das frutas e seu efeito sobre o ataque de pragas em pomar de goiaba e caqui, desenvolveram-se dois experimentos no período de 31 de janeiro a 6 de março de 2012, em Santa Maria, Estado do Rio Grande do Sul, Brasil. Em delineamento de blocos ao acaso sob esquema fatorial, avaliou-se o número médio de adultos de *Anastrepha fraterculus*, *Ceratitis capitata* (Diptera: Tephitidae) e *Zaprionus indianus* (Diptera: Drosophilidae) emergidos de frutos em duas situações (no chão e sobre a planta) e o número de adultos capturados por armadilhas frasco caça mosca em duas condições iniciais de volume, ambas sob diferentes diâmetros de furo e em diferentes dias após a colocação do atrativo alimentar. Diâmetros de tamanho menor apresentaram maior captura de adultos de *A. fraterculus*, *C. capitata* e *Z. indianus*. O diâmetro de 1,0 cm apresentou maior eficiência na redução da emergência de adultos de Tephritidae, para *Z. indianus*os menores diâmetros, 0,6 e 0,8 cm, apresentaram as maiores eficiências sobre a emergência de adultos de frutos de caqui e goiaba.

Palavras-chave: controle alternativo, *Anastrepha fraterculus*, *Ceratitis capitata*, *Zaprionus indianus*.

Introduction

In southern Brazil, Rio Grande do Sul State is the leading temperate fruit producer, although it faces phytosanitary problems from insects, particularlyfrom fruit flies (NUNES et al., 2012). Three species have been characterised as having major economic importance in the Central Depression region of the State, *Anastrepha fraterculus* (Wied., 1830), *Cetaritis capitata* (Wied., 1824) (Diptera: Tephritidae) and *Zaprionus indianus* Gupta 1970 (Diptera: Drosophilidae) (PASINI et al., 2012).

A. fraterculus and *C. capitada* are the principal pests in Brazilian fructiculture (ZART et al., 2011). These species are widely distributed throughout Brazil because of their high degree of polyphagia, adaptability to different climates, use of a variety of hosts and ease of dispersion (ZANARDI et al., 2011). These flies infest native and exotic fruit populations; damage is caused by females that pierce the fruits to deposit their eggs (RICALDE et al., 2012). As theyemerge, the larvae consume the pulp, which causes early maturation and premature fruit drop (LORSCHEITER et al., 2012).

*Z. indianus*is characterised as the most common fig pest (*Ficus carica* L.) in Brazil; it shows a high degree of polyphagia and a wide range of developmentalsubstrates (PASINI et al., 2011). This species attacks fig fruits at the beginning of the maturation phase, and the ovipositing posture is held in theostiole surrounded by bracts. Larvae development is associated with the presence of microorganisms; the development of the adult fliesdamages the fruit and renders it commercially unusable (MULLER et al., 2012; VILELA et al., 2000).

The use of food bait in trap bottles has been widely researched in Rio Grande do Sul State in the search for viable low-cost alternative protection measures withmilder environmental effects (PASINI et al., 2012). The reuse of PET bottles is becoming more popular not only because it employs "junk", but because the method captures fruit flies efficiently. Pasini and Link (2011) show that the performance of this type of trap reduces production costs and is more sustainable than commercial traps.

Commercial traps have an average acquisition cost per unit of R$ 15, whereas the plastic bottle traps have no cost. Both of these traps work with various types of food bait and their efficiencies are scientifically proven (LANG SCOZ et al., 2006; MEDEIROS et al., 2011; MONTEIRO et al., 2007; PASINI et al., 2011; PASINI; LINK 2011; RAGA et al., 2006; VILLAR et al., 2010). However, thereare differences between them, such as the substantial initial volume and large number of attractive solution exchanges in the commercial traps, in addition tothe shorter effective period of the attractive solution, which generates a greater cost with this solution.

This study aimed to measure the efficiency of different hole diameters in PET bottles in capturing fruit flies and of the effect of using such PET bottles to combat insect pests in guava and persimmon orchards.

Material and methods

Two experiments were conducted in the Fruit Sector at the Polytechnic College of the Federal University of Santa Maria, Rio Grande do Sul State, Brazil (29° 43'S; 53° 43'W, at approximately 96 m altitude) in the persimmon orchard (*Diospyros kaki*, L.) and guava orchard (*Psidium guajava* L.). The experimental area is situated in the physiographic region of the Central Depression, on the edge of the general mountain andwith a climate that is consistent with KÖPPEN classification, type Cfa (HELDWEIN et al., 2009).

The experiments were conducted from 31 January to 6 March 2012, while the orchards were in the production stage. We adopted a randomised block design with four replications and treatments in a factorial of 2 x 5 x 5, consisting oftwo volumes of attractive food (200 and 250 mL) xfive hole diameters (1.4, 1.2, 1.0, 0.8, and 0.6 cm) x five evaluation dates (7, 14, 21, 28 and 35 days after attractive placement[DAP]), in which each plant was one experimental unit.

The traps used were 0.6 LPET bottles (PASINI; LINK, 2011) that werearranged under the sunlight (facing west in relation to the vegetative canopy) with an average height above ground of 50 cm. The attractive solutionused was grape juice and water at a concentration of 25 and 75%, respectively (LANG SCOZ et al., 2006).

On a weekly basis, the adult *A. fraterculus*, *C. capitata* e *Z. indianus* that were captured were removed with the aid of a colander and conditioned in containers of a 0.2 L withalalcohol (70%). The attractive solution remaining was put back in the trap, where it stayed for five weeks. With the aid of a measuring cup, weekly evaluations were made of the solution volumes in different traps. During the execution of the experiments, attractive solution was not replaced or added to in the traps. The insects captured were sorted, identified and their frequencies quantified.

In determining the efficiency of traps, individual evaluations of guava fruits and persimmon fruits were conducted on a weekly basis from 31 January to 6 March 2012. Eight fruits from each plant with a trap were collected randomly from two situations, either from on the plant or from the soil. In addition, the third fruit was collected from the apex of the selected branch. The fruits were brought to the laboratory and placed in 0.5 Lcontainersto obtain adults. For each block was added one plant to determine the efficiency of the traps, which we termed the attestant. For this determination we adopted a factorial 2x6x6, consisting of two situations of collection of fruits (in the plant and on the soil) x five hole diameters (1.4, 1.2, 1.0, 0.8 and 0.6 cm andattestant) x six evaluation dates (7, 14, 21, 28 and 35 days after attractive placement [DAP]); the numbers of adults of *A. fraterculus*, *C. capitata* and *Z. indianus* that emerged from the fruit were evaluated.

The data obtained on the number of insects captured and emerged were transformed ($\sqrt{x+0,5}$) and submitted to ANOVA and Tukey's test for comparison of means and regression analyses. Within each treatment, Tephritidae species were compared by a t test. For all statistical analysis, a 5% probability of error was adopted. The efficiency of the traps was calculated from Abbott's formula (1925). The temperature and the relative air humidity (obtained from the meteorological station at the Federal University of Santa Maria, 300 meters from the experimental area) was applied to the analysis of the Pearson linear correlation (R) between the observed variables.

Results and discussion

During the 35 – Day period, 14,662 adults of *Zaprionus indianus* were captured by PET bottle traps, with na average catch per trapo f 73.31, which in higher than that found by Pasini et al. (2011) and Pasini et al. (2012) in a fig orchard (9.5 adults per trap) and a guava orchard (26.14 adults per trap), respectively, which represents a significant difference with the Tephritidae population captured. During the same period, there werw only 694 *Ceratitis capitata* and 452 *Anastrepha fraterculus* individuals captured, which represents a low catch, with na average catch per trap of 3.47 and 2.26, respectively, which shows no significant difference under the t test.

The average number of *Z. indianus* adults was significantly influenced by the attractive solution volume, by the different hole diameters and by the number of days after the placement of attractive solution and showed a significant interation between the three factors. The largest captured populations were in traps containing 250 mL of solution (Figure 1), with different emergence rates for different DAP in different hole diameters. Traps that initially contained 250 mL exhibited a positive linear response for the traps with smaller diameters (between 1.0 and 0.6 cm) and negative quadratic in the traps with larger diameters. In the volume, the highest capture was recorded at 35 DAP which justified the efficient use of the traps with diameters less than 0.8 cm for more of 35 days.

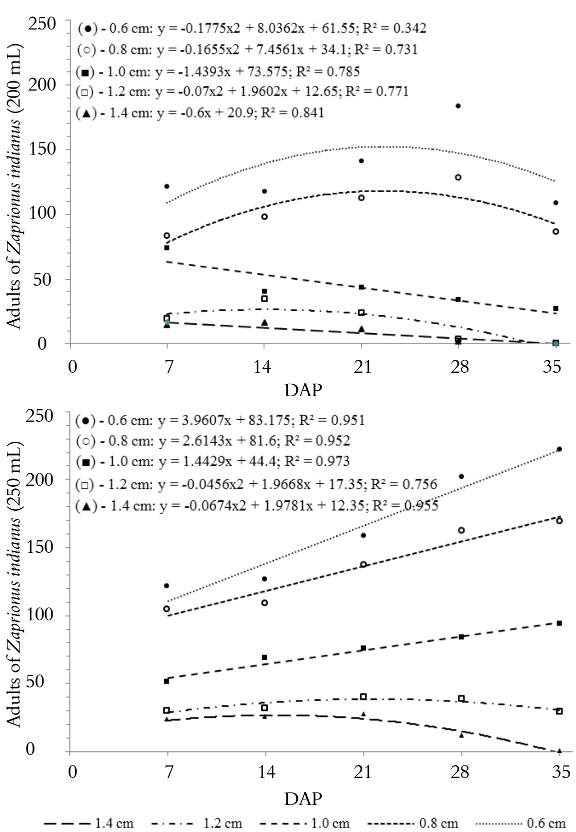

Figure 1. *Zaprionus indianus* adults captured (in two volumes of attractive solution, 200 and 250 mL) by PET trap bottles with different hole diameters and a different numbers of days after placement of attractive solution near Santa Maria, Rio Grande do Sul State, Brazil, 2011.

Mosto f the traps initially containing 200 mL showed a negative quadratic behaviour, which is similar to that found by Pasini et al. (2012) in the PET bottle traps with hole diameters of 0.8 cm (except for traps with hole diameters of 1.4 and cm, which presented a negative linear behaviour). In this volume, down to a 0.6 cm hole diameter, the equation only partially explains the rate of capture (Figure 1) up to 21 DAP, which showed average catch in each volume; for others, the coefficients were greater than 70%

The average number of Tephritidae was significantly influenced by the volume of attractive solution utilised by the different hole diameters and by the days after placement of the attractive solution. For C. capitata, there was significant interaction between the different diameters and different DAP (and for most capture rates accounted for by negative linear models); for diameters of 0.8 and 1.0 cm, the capture showed cubic behaviour (Figure 2). The highest capture levels were recorded at 7 DAP.

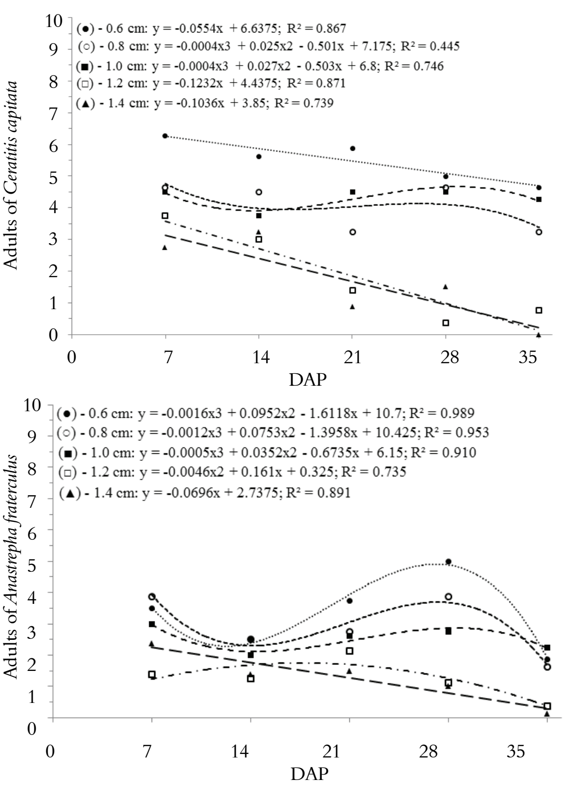

Figure 2. Captured Tephritidae adults (*Anastrepha fraterculus* and *Ceratitis capitata*) by PET trap bottles with different hole diameters and different days after placement of attractive solution in Santa Maria, Rio Grande do Sul State, Brazil, 2011.

For *A. fraterculus*, there was no interaction between the three evaluated factors. The highest captures were at 28 DAP for hole diameters between

0.6 and 1.0 cm. However, for the larger diameters, the highest capture levels were recorded at 7 and 21 DAP for 1.4 and 1.2 cm diameters, respectively (Figure 2). According to Salles (1999), the aging and the decomposition of the attractive solution is a positive factor and has a direct relationship toan increasein captured fruit flies; this relationship is valid for *A. fraterculus* (Figure 2) and contrastswith what was found for *C. capitata*. In this case, the aging effect of the attraction solution has an indirect relationship with the capture.

The average capture rates of *A. fraterculus* were lower than those obtained by Lang Scoz et al. (2006) and Monteiro et al. (2007) with grape juice, by Raga et al. (2006) with citrus orchard, and by Villar et al. (2010) and Medeiros et al. (2011) with passion fruit juice, mango juice and guava juice. In two tested volumes, there was a significant difference under a t test for both Tephritidae species. Traps with 250 mL had the highest capture levels, which is different that found by Raga et al. (2006), in which no significant difference found among the evaluated Tephritidae species.

The smaller hole diameters had the highest capture levels for all evaluated species (Figure 3) presented among the species, and the different diameters had a negative correlation (R > -0.7). Traps with an initial volume of 250 mL afforded the highest average capture and showed a difference of 30 individuals with other diameters. The average captures obtained in with the 0.8 cm diameter holesand 200 mL of initial volume were higher than those found by Pasini et al. (2011) in a fig orchard under identical conditions and attractive solution, which indicates a higher population of *Z. indianus* in guava and persimmon orchards (PASINI et al., 2012). For the Tephritidae species, the capture results were linearly negative (Figure 3), with *C. capitata* presenting the highest average capture.

The volume change of the attractive solution was significantly influenced by the initial solution volume, by the different hole diameters of PET trap bottles and by the number of days after placement of the attractive solution; there was a significant interaction between the three factors. Traps with larger diameters had the highest volume losses of the different initial volumes tested (Figure 4). The volume variation presented a positive correlation with DAP difference (R > 0.7); this relationship is similar to that found in different traps by Pasini and Link (2011),which indicates that the greater the DAP, the greater the change in volume and, consequently,the lower the volume of solution that remains in the PET trap bottle.

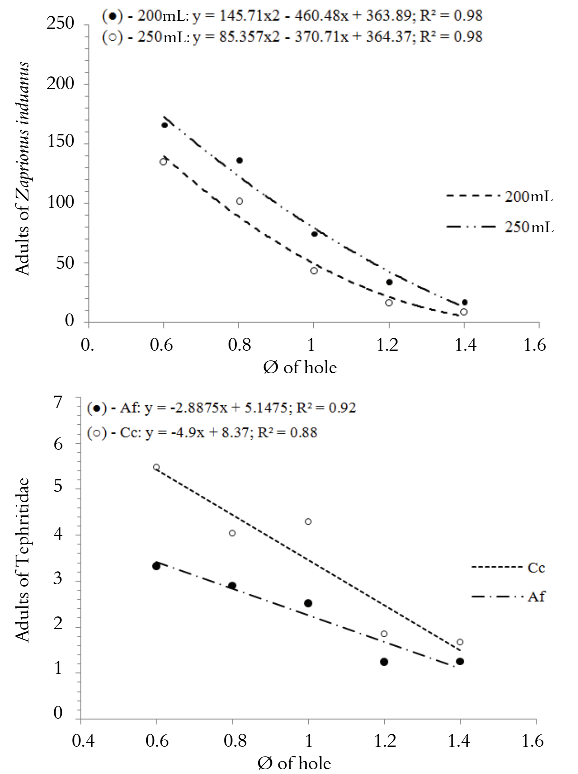

Figure 3. Average number of captured Tephritidae adults [*Anastrepha fraterculus* (*Af*) and *Ceratitis capitata* (*Cc*)] and *Zaprionus indianus* (*Zi*) by PET bottle traps with different hole diameters with two different volumes of attractive solution, 200 and 250 mL. Santa Maria, Rio Grande do Sul State, Brazil, 2011.

In the smaller diameters (0.6 and 0.8 cm), there was a difference between the initial volumes tested, when the traps with 250 mL presented less volume variation than those with 200 mL (Figure 4). This result may be associated withwater specific heat because bottles with greater initial volume will require a greater amount of energy to heat up and consequently a smaller amount of solution will evaporate.

A smaller-sized diameter hole also contributes to a smaller air passage and a smaller exposure surface for the attractive solution. This argues against larger hole diameters; regardless of the initial volume, the variations were high, as shown in the results for diameters of 1.4 and 1.2 cm with 200 mL and for adiameter of 1.4 cm with 250 mL, in which the variation was equal to the initial volume (Figure 3). Traps with a 1.2 cm hole and an initial volume of 250 mL (although there is a variation equal to 1.2 cm in 200 mL) maintained capture to 35 DAP (Figure 1), which is associated with the presence of attractive solution in the trap.

The influence of the attractive solution volumewas affectedbeginning at 21 DAP (Figure 5); the traps with smaller diameters increase capture efficiency instead of losing it. This result shows the efficiency of using smaller hole diameters for longer periods compared to larger diameters.

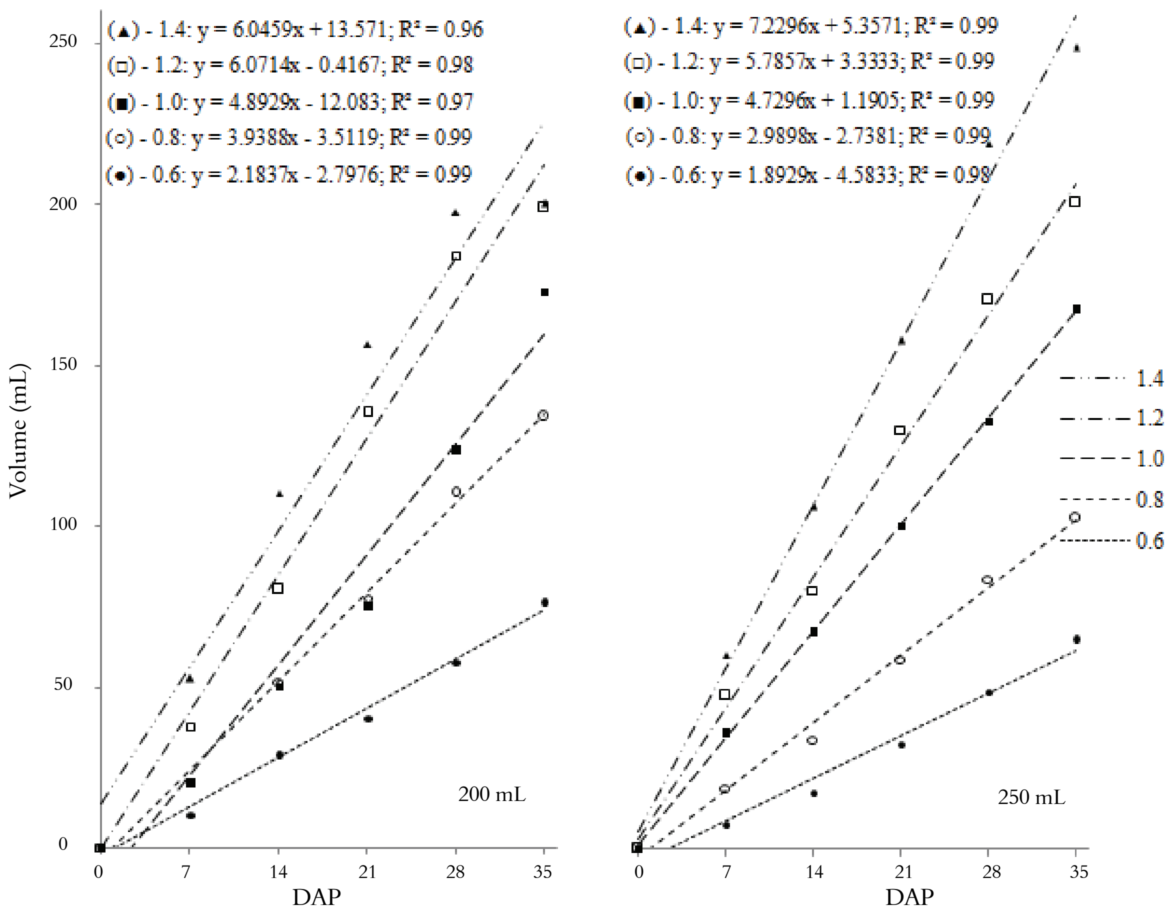

Figure 4. Average volume variation (first volume – last volume), in the quantity of attractive solution in different hole diameters by the two first conditions for different days after placement of attractive solution (DAP) in Santa Maria, Rio Grande do Sul State, Brazil, 2011.

Traps with larger diameters presented smaller efficiency in capturing insects, which may be associated with insect entry and exit of the trap hole and arresting them in the traps. Traps with 1.4 cm diameter, for example, have 1.53 cm^2 for the entry of insects, unlike traps with 0.8 and 0.6 diameter holes that have 0.50 and 0.28 cm^2 for the entry of insects, respectively.

The larger orifice area contributed to the insects exit and to the greatest attractive solution evaporation. For the entry of insects into the trap, the diameter effect only serves as a physical barrier in which the larger insects, such as *Apis mellifera*, are barred from entering, and does not influence the attractiveness and dispersion of odor from the attractive solution fermentation, which is a mechanism that attracts adult insects in theory (SALLES, 1999).

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These results show that the capture of insects by PET traps bottles is directly associated with the quantity of the remaining attractive solution in the trap, the trap type and the diameter of the entry hole.

Of the different fruitsevaluated to determine the PET trap bottle efficiency, 9,148 *Z. indianus* emerged, which is an average emergence of 31.8 individuals per fruit and is similar to that found in fig fruits by Pasini and Link (2012), which was 34.1 individuals per fruit. Of the two Tephritidae species, 1,233 individuals emerged (635 *A. fraterculus* and 598 *C. capitata*), which is an average emergence of 2.2 and 2.1 individuals, respectively.

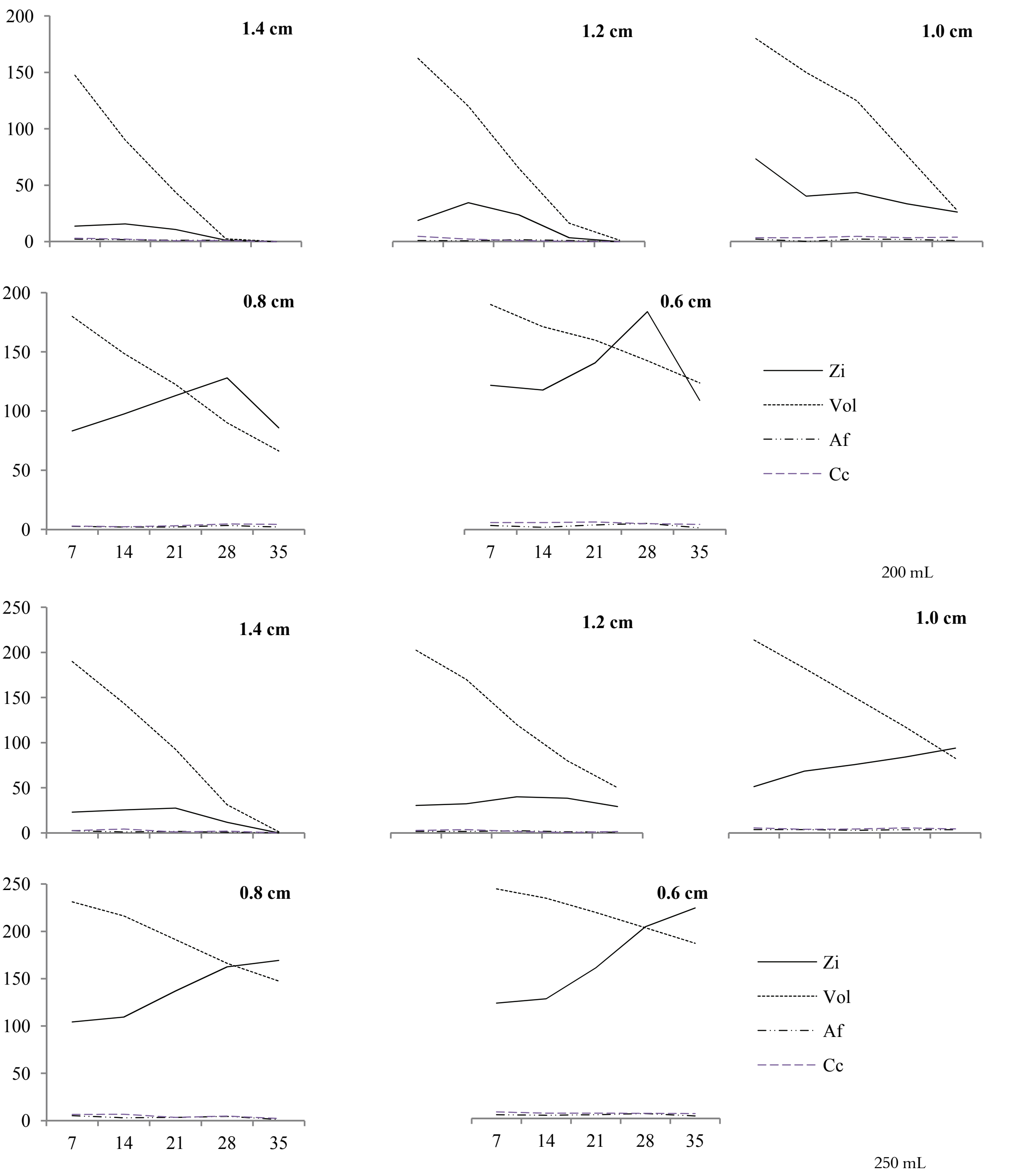

Figure 5. Average capture of adults of *Zaprionus indianus* (*Zi*), *Anastrepha fraterculus* (*Af*) and *Ceratitis capitata* (*Cc*) and the average volume comportment of attractive solution (Vol) in mL, with different hole diameters of the PET trap bottles for different days after placement of attractive solution (DAP) in Santa Maria, Rio Grande do Sul State, Brazil, 2011.

These results were different from the proportion of species observed by Nunes et al. (2012) in the cities of Pelotas and Capão do Leão, RS (approximately 90% of emerged specimens were*A. fraterculus*), although the regions have the same type of weather, Cfa; regional factors (such as the diversity and quantity of host plants) may be the cause of such difference.

Significant differences were observed in hole diameters and different DAP with the two tested situations (on the plant and in the soil) for the two evaluated Tephritidae species, with significant interaction between the situation and the days after the placement of the attractive solution. In the plant fruits collected, quadratic behaviourwas obtained for *C. capitata* and *A. fraterculus*, and the largest population of insects emerging in fruits was at 0 DAP (Figure 6).

These results indicatethat the traps affect the place that pests attack in the fruit. For fruits located on the soil, aninverse capture rateobtained compared the fruits on the plant because the largest population was found at 14 days for *A. fraterculus* and *C. capitata*, which indicates that the placement of the trap with the attractive solution did not influence Tephritidae emergence (Figure 6).

For the different hole diameters of the traps, the adult fruit emergence of *A. fraterculus* and *C. capitata* was not significant. This result was different from that obtained by Moura and Moura (2006), in which guava fruits showed a higher infestation of *C. Capitata*, and by Nunes et al. (2012) in which 95% of the emerged specimens were *A. Fraterculus*; however, this species was not found in persimmon fruits, in which only *C. Capitata* were found (Table 1).

There was significant difference between attestant and hole diameters for the two species. For*A. fraterculus*, diameters of 0.6, 1.0 and 1.4 cm presented the greatest reduction in the emerged population, indicating that efficiencies higher than 40% were achieved. As for *C. capitata*, the greatest reductions in emerged populations were observed for diameters between 0.8 and 1.2 cm, with efficiencies above 50% (Table 1). Although less efficient, the use of PET trap bottles associated with other management practices, such as fruit collection on the soil, can contribute to increasing control efficiency. For the two species, a 1.0 cm diameter was the most efficient, although with lower capture levels than the 0.6 cm diameter (Figure 3). During the execution of the experiment, there was no adult emergence of *Z. indianus* in fruit on the plants. These results indicate that the adult insects are unable to piercethe persimmon and guava epicarp and require some type of injury to take advantage of the fruit endocarp. At 0 and 7 DAP, there were no differences obtained between the means of tested treatments (Table 2).

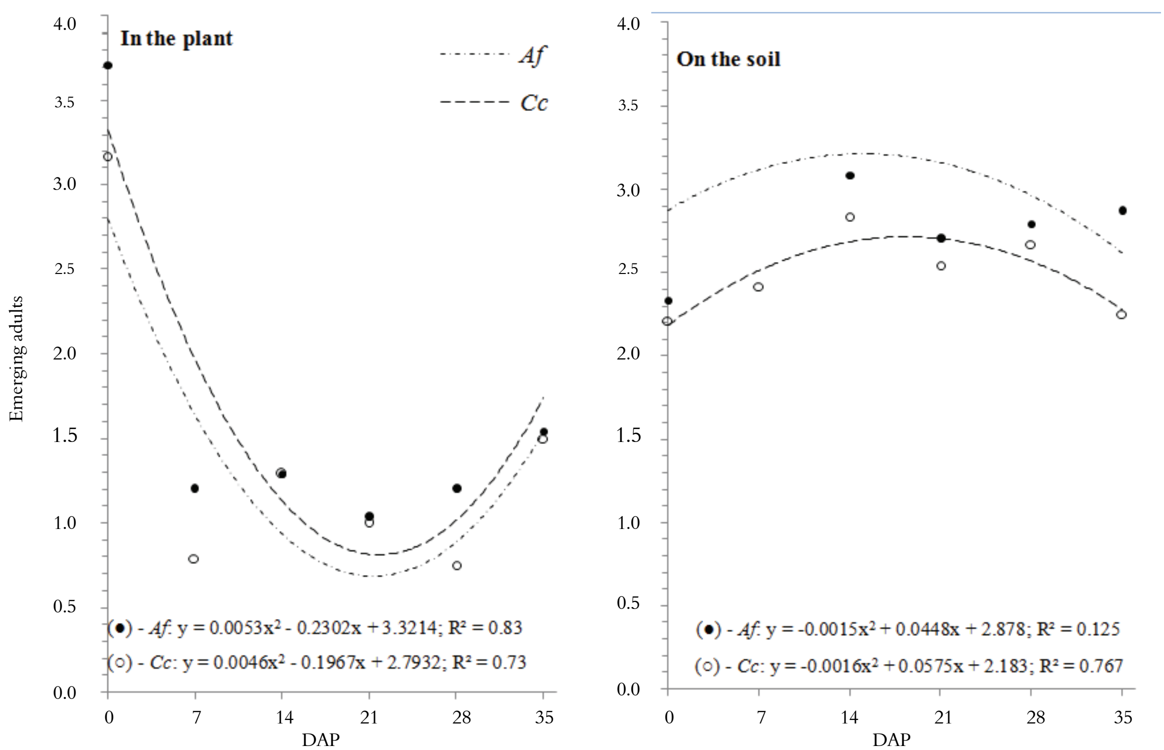

Figure 6. Adults of *Anastrepha fraterculus* (*Af*) and *Ceratitis capitata* (*Cc*) emerging in fruits,on plants and in the soil,on different days after attractive solution placement (DAP). Santa Maria, Rio Grande do Sul State, Brazil, 2011.

Table 1. Number (n), oratory (Σ), average ($\bar{x}$), standard deviation (sd) of fruit with insect emergency and efficiency (Abbott, E%) for different hole diameters in PET trap bottles on the emergence of Tephritidae (Diptera). Santa Maria, Rio Grande do Sul State, Brazil, 2011.

Hole Ø (cm)	*Anastrepha fraterculus*						*Ceratitis capitata*						t test
	n	Σ	$\bar{x}$		sd	E%	n	Σ	$\bar{x}$		sd	E%	
1.4	48	91	1.90	b*	2.10	41.7	48	91	1.90	ab	2.23	47.1	ns[1]
1.2	48	113	2.35	ab	2.31	27.6	48	82	1.71	b	1.81	52.3	ns
1.0	48	91	1.90	b	1.86	41.7	48	72	1.50	b	1.80	58.1	ns
0.8	48	97	2.02	ab	2.47	37.8	48	86	1.79	b	2.05	50.0	ns
0.6	48	87	1.81	b	2.11	44.2	48	95	1.98	ab	2.25	44.8	ns
Attestant	48	156	3.25	a	1.91	-	48	172	3.58	a	2.30	-	ns
$\bar{x}$			2.20						2.08				
CV%[6]			98.69						104.93				

*Averages not followed by the same letter differ significantly under Tukey's test at 5%. [1]ns: not significant among Tephritidae species of the t test at 5%.

Table 2. Number (n), somatory (Σ), average ($\bar{x}$), standard-deviation (sd) of fruits with insect emergence and the efficiency (Abbott, E%) of different hole diameters in PET trap bottles with respect to the emergence of *Zaprionus indianus* (Diptera: Drosophilidae). Santa Maria, Rio Grande do Sul State, Brazil, 2011.

Ø de furo (cm)	n	Σ	$\bar{x}$		sd	E%	n	Σ	$\bar{x}$		sd	E%
	0 DAP						7 DAP					
1.4	4	276	69.0	a	48.1	-	4	323	80.8	a	38.4	-
1.2	4	195	48.8	a	44.9	-	4	245	61.3	a	22.7	23.7
1.0	4	199	49.8	a	9.6	-	4	232	58.0	a	24.1	27.7
0.8	4	257	64.3	a	26.1	-	4	246	61.5	a	6.2	23.4
0.6	4	382	95.5	a	14.2	-	4	182	45.5	a	8.8	43.3
Attestant	4	336	84.0	a	3.7		4	321	80.3	a	1.0	
$\bar{x}$			68.5						64.5			
CV%			46.0						35.1			
	14 DAP						21 DAP					
1.4	4	290	72.5	ab	21.0	21.0	4	267	66.8	ab	22.4	40.7
1.2	4	253	63.3	ab	33.1	31.1	4	227	56.8	ab	13.5	49.6
1.0	4	226	56.5	ab	11.0	38.4	4	272	68.0	ab	22.0	39.6
0.8	4	170	42.5	b	21.8	53.7	4	206	51.5	b	19.7	54.2
0.6	4	177	44.3	ab	14.5	51.8	4	156	39.0	b	10.5	65.3
Attestant	4	367	91.8	a	17.7		4	450	112.5	a	8.3	
$\bar{x}$			61.8						65.8			
CV%			41.1						42.5			
	28 DAP						35 DAP					
1.4	4	306	76.5	ab	12.4	39.8	4	269	67.3	ab	21.4	47.9
1.2	4	155	38.8	c	22.3	69.5	4	132	33.0	b	6.1	74.4
1.0	4	209	52.3	bc	21.8	58.9	4	214	53.5	ab	35.9	58.5
0.8	4	152	38.0	c	14.8	70.1	4	141	35.3	b	6.3	72.7
0.6	4	132	33.0	c	4.2	74.0	4	159	39.8	b	21.2	69.2
Attestant	4	508	127.0	a	16.1		4	516	129.0	a	38.3	
$\bar{x}$			60.9						59.6			
CV%			60.1						67.9			

*Averages not followed by the same letter differ significantly under Tukey's test at 5%.

At 14 DAP, significant differenceswere observed between the attestant and the 0.8 cm diameter hole, with an efficiency higher than 50%; from 21 DAP, the smallest diameters showed more efficiency and the 28 and 35 DAP showed greater than 70% efficiency. These results indicate a significant reduction in the average number of adults of *Z. indianus* emerging from guava fruit and persimmon fruit on the soil (Table 2). In comparison with the results obtained in the capture of diameters different (Figure 3), this effectresults in the greatest capture of the smaller diameter on the population of *Z. indianus*. For this species, the diameter of 0.8 and 0.6 cm presented more capture efficiencies, but this does not justifyonly the use of attractive solution in PET trap bottles because this alternative should be used with other techniques to pest population control.

Although *Z. indianus* has no economic effect on persimmon and guava crops, orchards of these crops can be characterised as insect pest disseminators because ofthe emergence rates obtained in the DAP that were different from the attestant, which were over 100 individuals per fruit, in certain cases (Table 2). The characteristics of Rio Grande do Sul State that includesimilar properties and orchards with high diversity of temperate fruit trees (ZANARDI et al., 2011) requires joint action in insect pest management that must be established for regions producing fruit that are consistent withthe fructification dynamics of orchards.

Conclusion

Smaller hole diameters present higher capture rates of adult *Anastrepha fraterculus*, *Ceratitis capitata* (Diptera: Tephitidae) and *Zaprionus indianus* (Diptera: Drosophilidae).

The hole diameter of 1.0 cm is more efficient to control Tephritidae adult emergence. For *Z. indianus*, the smaller hole diameters have higher efficiencies in controlling adult emergence inguava and persimmon fruit.

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