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Use of andiroba oil to control *Anastrepha fraterculus* (Diptera: Tephritidae) in different fruit hosts

Uso de aceite de andiroba para controlar *Anastrepha fraterculus* (Diptera: Tephritidae) en diferentes hospedadores de frutas

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Abstract: Control of *Anastrepha fraterculus* (Diptera: Tephritidae) is usually accomplished with synthetic insecticides, which can be a problem considering the exportation of fruits. This study aimed to evaluate mortality and offspring effects on *A. fraterculus* using peach, strawberry guava and apple fruits treated with andiroba (*Carapa guianensis*) oil. Higher mortality rate was observed when compared to control on strawberry guava and apple fruits treated with andiroba oil (18.4 % and 35.0 % points more than the control). The mean number of pupae observed in the offspring was inferior to the control on strawberry guava and apple fruits treated with andiroba oil (100 % control) and, on peach fruits (68.3 % fewer pupae). Andiroba oil shows promising results as an alternative product to control *A. fraterculus*. Studies are still needed especially considering the effectiveness of andiroba oil under field conditions.

Keywords: Fruit flies, extracts, andiroba oil, alternative control.

Resumen: El control de *Anastrepha fraterculus* (Diptera: Tephritidae) generalmente se realiza con insecticidas sintéticos, lo que puede ser un problema si se considera exportar frutas. Este estudio tuvo como objetivo evaluar la mortalidad y el efecto de la descendencia en *A. fraterculus* en frutas de duraznos, guayabos peruanos y manzanas tratadas con aceite de andiroba (*Carapa guianensis*). Se observó una mayor tasa de mortalidad en comparación con el control para las frutas de guayabo peruano y manzana tratadas con aceite de andiroba (incremento del 18,4 % y 35,0 % puntos más que el control). El número medio de pupas observado en la descendencia fue inferior al control de guayabos peruanos y frutas de manzana tratadas con aceite de andiroba (control 100 %) y en frutas de durazno (68,3 % menos pupas). El aceite de andiroba muestra resultados prometedores como un producto alternativo para controlar *A. fraterculus*. Son necesarios más estudios, en especial al considerar la efectividad del aceite de andiroba en condiciones de campo.

Palabras clave: Moscas de la fruta, extractos, aceite de andiroba, control alternativo.

Introduction

One of the main pests of fruit crops in Brazil is the South American fruit fly *Anastrepha fraterculus* Wiedemann, 1830 (Diptera: Tephritidae) which can cause damage in more than 115 fruit species (Zucchi and Moraes 2008). The predominant method to control *A. fraterculus* is the application of synthetic insecticides which may leave residues on fruits. This condition can be a major problem for exportation since many importing countries input strict limits on the amount of residue allowed (Handford *et al.* 2015).

The scientific literature suggests the use of botanical insecticides as alternatives to control pests. These products are becoming increasingly popular since some

countries simplified their commercial registration (Isman 2015). Botanical insecticides have some advantages over synthetic insecticides as they are generally rapidly degraded in the environment and have a low production cost (Isman 2006).

The andiroba tree (*Carapa guianensis* Aubl., 1775) (Meliaceae) oil extracted from its seeds is one of the botanicals that has been proven to be effective to control some insects (Sarria *et al.* 2011; Prophiro *et al.* 2012). Besides, andiroba oil when administered to pregnant rats showed no toxicity to fetuses (Costa-Silva *et al*. 2007). No mutagenic, hemotoxic or genotoxic effect was also observed in another study with rats (Milhomem-Paixão *et al.* 2016). Although more studies need to be carried to access its toxicity in humans, andiroba oil seems to be an alternative and a safe product to be used instead of synthetic insecticides.

The goal of this study was to identify whether the deleterious effect found in other insects can also be observed in *A. fraterculus* in peach, apple and strawberry guava fruits treated with andiroba oil under laboratory conditions.

Materials and methods

The experiment was carried out at the laboratory of Santa Catarina State University (UDESC) (- 27.7922ºS 50.3050ºW) from January to July 2016. Peach (*Prunus persica* L. 'Chimarrita') (Rosaceae), strawberry guava (*Psidium cattleianum* Sabine var. *Cattleyanum*) (Myrtaceae) and apple (*Malus domestica* Borkh 'Fuji') (Rosaceae) fruits were previously bagged from trees of the campus to prevent field infestation. Peach and strawberry guava fruits were harvested when they reached 10 ºBx while apples were harvested at the starch-iodine index of 4 using a 1 to 5 scale in which 1 indicates the least and 5 the most starch to sugar conversion.

Andiroba oil (*Carapa guianensis*) was purchased pure and diluted in ethanol 70 % at 25 % (v/v) concentration. Rearing of *A. fraterculus* followed the method adopted by Nunes *et al.* (2015).

The experiment was carried out in a completely randomized design (3 fruits species x 1 botanical substances and 1 control, 10 replicates). Each fruit was immersed for 30 seconds in andiroba oil or in 70 % ethanol (control), which were constantly being stirred by a magnetic stirrer, and left to dry for 5 min on a paper towel. Ethanol was used as a control treatment, as it was also used to dilute andiroba oil.

Each fruit was transferred to containers (750 ml) and afterwards two adult couples of *A. fraterculus* (15 to 20 days old) were released into each container for 48 hours and maintained in a climatized chamber (25 ± 2 °C and RH 60 ± 10 %). Adult mortality was assessed after this period. The fruits were then transferred to new containers containing vermiculite and returned to the chamber for a period of 20 days. The number of insects in offspring was quantified by sieving the vermiculite and counting the number of pupae.

Data were submitted to the SAS software 9.4 University Edition (SAS institute 2015). Analysis of variance (ANOVA) was performed using the GLIMMIX procedure. The data were transformed to better fit the residuals to a Gaussian distribution using Box-Cox. Homoscedasticity and fitness of the distribution to the model were verified by diagnostic plots. Fisher's LSD test was performed by using the % MULT macro (Piepho 2012).

Results

Adult mortality evaluation. Mortality of *A. fraterculus* was significantly affected by the treatment applied to the fruits and the interaction Treatment*Fruit species ($P < 0.05$) (Table 1). Andiroba oil caused mortality of 35.0 % points higher than the control in strawberry guava fruits and 18.4 % points higher than the control in apple fruits. The insecticidal effect of the andiroba oil was much more pronounced on apples and strawberry guava than on peach fruits (Table 1).

Offspring evaluation. Offspring of *A. fraterculus* was significantly affected by the treatment applied to the fruits and the fruit species ($P < 0.05$) (Table 2). A reduction in the number of insects in offspring compared to the control was observed in peach and apple fruits treated with andiroba oil (68.3 % and 100 % fewer pupae observed). No significant difference was observed on treated strawberry guava fruits, nevertheless, no pupae were obtained in fruits treated with andiroba oil. The effect of the andiroba oil was once again more pronounced on strawberry guava and apple fruits than on peach fruits (Table 2).

Discussion

The explanation of the different results found in peach compared to the other fruits might be due to the different epidermis. While peaches present hairy epidermis, apple and strawberry guava fruits present smooth and glabrous epidermis which allow volatiles to be more easily released. Grammatikopoulos and Manetas (1994) complement by reporting that leaves with trichomes enable greater retention of liquids and consequently reduce the process of volatilization.

The insecticidal effect of andiroba oil may be related to the presence of gedunin, a limonoid present in the *Carapa* genus (Ambrozin *et al.* 2006) that is a potential antifeedant (Mikolajczak *et al.* 1988). The lethal effect of andiroba oil was observed in several species such as: the yellow fever mosquito (*Aedes* spp.) (Prophiro *et al.* 2012); fall armyworm (Sarria *et al.* 2011); brown dog tick [*Rhipicephalus sanguineus* (Latreille, 1806)] (Roma *et al.* 2015); maize weevil (*Sitophilus zeamais* Motschulsky, 1885) (Santos *et al*. 2015); as well as in *A. fraterculus* using pears (*Pyrus communis*) as hosts (Nunes

Table 1. Mean (± SE) adult mortality (%) of *Anastrepha fraterculus* after 48 h of exposure to fruits treated with andiroba (*Carapa guianensis*) oil. Summarized ANOVA table for each fixed effect considered in the model.

Treatment	Fruit species		
	Strawberry guava	Peach	Apple
Andiroba oil	37.50 ± 4.93 aA	5.00 ± 3.25 aB	20.45 ± 3.88 aA
Ethanol 70 % (control)	2.50 ± 2.81 bA	15.00 ± 4.59 aA	2.08 ± 2.69 bA

Fixed effect	Num DF	Den DF	F value	P-value
Treatment (T)	1	50	14.07	0.0004
Fruit species (F)	2	50	1.17	0.3174
Interaction T*F	2	50	9.04	0.0004

[1] Means followed by same lowercase letters among treatment in each fruit species and uppercases letters among fruit species in each treatment do not differ significantly by the Fisher's LSD test ($P > 0.05$).

Table 2. Mean (± SE) number of pupae observed in the second generation following a 48 h exposure of fruits treated with andiroba (*Carapa guianensis*) oil to *Anastrepha fraterculus* adults. Summarized ANOVA table for each fixed effect considered in the model.

Treatment	Fruit species		
	Strawberry guava	Peach	Apple
Andiroba oil	0.00 ± 0.00 aA	7.00 ± 3.56 aB	0.00 ± 0.00 aA
Ethanol 70 % (control)	1.40 ± 1.38 aA	22.10 ± 5.11 bB	4.92 ± 1.91 bB

Fixed effect	Num DF	Den DF	F value	P-value
Treatment (T)	1	50	23.21	< 0.0001
Fruit species (F)	2	50	8.16	0.0008
Interaction T*F	2	50	1.41	0.2526

[1] Means followed by same lowercase letters among treatments in each fruit species and uppercases letters among fruit species in each treatment substance do not differ significantly by the Fisher's LSD test (P > 0.05).

et al. 2015). Additionally, the seeming repellent effect of the andiroba oil might be caused by its oily properties since lipids tend to provide a slipperier surface that discourages fruit fly oviposition (Hidayat *et al.* 2013). A similar repellent effect of andiroba oil was also observed by Rosa *et al.* (2013), which found that andiroba oil used in field traps significantly reduced the number of *A. fraterculus* adults captured.

Conclusion and recommendations

Andiroba oil caused adult mortality of *A. fraterculus* in treated strawberry guava and apple fruits as well as prevented its complete proliferation in the same fruits. The effect of the andiroba oil on peach fruits was only observed in the offspring as it reduced the number of pupae compared to the control by 68.3%. It is recommended that other extraction methods should be tested since depending on the method adopted different concentrations of the constituents may predominate. More detailed studies are required to best access the effectiveness of the andiroba oil under field conditions.

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Author contribution

The first author conducted the experiments, collected the data, performed statistical analyses and wrote the draft and final result of the paper. Second, third and fourth authors helped collect the data and provided suggestions to improve the final result of paper. Fifth, sixth, seventh and eighth authors supervised the conduction of experiments, provided mentorship, helped in the acquisition of the andiroba oil and funding for the project.