

Antixenosis of the Triozid, *Triozoida limbata* (Hemiptera: Triozidae) to Some Cultivars of *Psidium guajava* (Myrtaceae) in the Field

Authors: de Oliveira, Isaías, Uchoa, Manoel A., Fernandes, Marcos G., Vieira, Cássia R. Y. I., Faccenda, Odival, et al.

Source: Florida Entomologist, 102(4) : 695-700

Published By: Florida Entomological Society

URL: <https://doi.org/10.1653/024.102.0404>

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Antixenosis of the trioqid, *Triozoida limbata* (Hemiptera: Triozidae) to some cultivars of *Psidium guajava* (Myrtaceae) in the field

Isaias de Oliveira¹, Manoel A. Uchoa^{2,*}, Marcos G. Fernandes², Cássia R. Y. I. Vieira¹, Odival Faccenda³, and Inessa S. T. de Oliveira⁴

Abstract

In the guava crop, insecticides are frequently used throughout the yr in an attempt to protect new shoots from the attack of the key pest *Triozoida limbata* (Enderlein) (Hemiptera: Triozidae). Research is essential to investigate the resistance of cultivars for management of *T. limbata* populations in sustainable production systems. We evaluated the preference of *T. limbata* on guava cultivars in the field, and determined the longitudinal and transverse incidence of the trioqid for plants of *Psidium guajava* L. (Myrtaceae). The evaluations were carried out in an orchard located in the Embrapa Agropecuária Oeste, Dourados, Mato Grosso do Sul, Brazil, with 8 cultivars of *P. guajava*, from May 2013 to Jul 2014. There were 96 plants in the area used; they were evaluated biweekly, quantifying the number of immatures and adults of the trioqid using new leaves from the apex of the branches to the second pair of leaves fully expanded in 4 main branches (branches leaving the trunk) per plant. Simultaneously, to capture adults 96 plants were monitored with a yellow adhesive trap (10 × 15 cm) fixed at the height of the canopy, and the traps were changed every 15 d. The cultivars ‘Cascuda’ and ‘Kumagai’ were non-preferred for immatures of *T. limbata*, whereas ‘Paluma’, ‘Tailandesa’, ‘Novo Milênio’, and ‘Pedro Sato’ cultivars were susceptible. There was a significant difference in the incidence of *T. limbata* adults between ‘Sassaoka’ and ‘Paluma’ cultivars. For the adults caught in adhesive traps, ‘Sassaoka’, ‘Kumagai’, and ‘Cascuda’ cultivars were not preferred, compared to ‘Paluma’ (susceptible). No difference occurred in the incidence of nymphs and adults of *T. limbata* between the positions of the branches, nor between plants or streets. The ‘Cascuda’ and ‘Kumagai’ cultivars are promising for guava breeding programs, aiming at resistance to *T. limbata* attack. To sample for *T. limbata* in orchards, one can evaluate the leaves of any of the 4 main branches that leave the trunk.

Key Words: guava crop; horticulture; trioqid; key guava pest; resistance of plant to insects

Resumo

Na cultura da goiaba são empregados inseticidas com frequência durante todo o ano, na tentativa de proteger as brotações novas do ataque da praga-chave *Triozoida limbata* (Enderlein) (Hemiptera: Triozidae). Pesquisas são imprescindíveis para investigar a resistência de cultivares para manejar populações de *T. limbata* em sistemas de produção sustentável. Avaliamos a preferência de *T. limbata* por cultivares de goiaba em campo e a incidência longitudinal e transversal do trioquídeo em plantas de *Psidium guajava* L. (Myrtaceae). As avaliações foram realizadas em pomar localizado na Embrapa Agropecuária Oeste, Dourados, Mato Grosso do Sul, Brasil, com 8 cultivares de *P. guajava* (maio de 2013 a julho de 2014). As plantas da área útil, 96 foram avaliadas quinzenalmente, quantificando o número de imaturos e adultos do trioquídeo nas folhas novas desde o ápice dos ramos até o segundo par de folhas totalmente expandidas em quatro ramos principais (ramos que saem do tronco) por planta. Além disso, as 96 plantas foram monitoradas com armadilhas adesivas amarela (10 × 15 cm) fixada na altura da copa para captura de adultos e foi trocada a cada 15 dias. Em ramos, os cultivares ‘Cascuda’ e ‘Kumagai’ foram caracterizadas como não preferidas por imaturos de *T. limbata*, enquanto os cultivares ‘Paluma’, ‘Tailandesa’, ‘Novo Milênio’, e ‘Pedro Sato’, foram susceptíveis. Houve diferença significativa da incidência de adultos de *T. limbata* apenas entre os cultivares ‘Sassaoka’ e ‘Paluma’. Já para adultos capturados em armadilhas adesiva, os cultivares ‘Sassaoka’, ‘Kumagai’, e ‘Cascuda’ não foram preferidas, quando comparadas com ‘Paluma’ (suscetível). Não houve diferença da incidência de ninfas e adultos de *T. limbata* entre as posições dos ramos: nem entre plantas, nem entre ruas. As cultivares ‘Cascuda’ e ‘Kumagai’ são promissoras para programas de melhoramento de goiabeiras visando à resistência ao ataque de *T. limbata*. Em *P. guajava* para amostragens de *T. limbata* em campo, podem ser avaliadas folhas novas de qualquer um dos ramos principais.

Palavras Chave: cultura da goiaba; fruticultura; trioquídeo; praga chave da goiabeira; resistência de planta a insetos

¹Agência de Desenvolvimento Agrário e Extensão Rural, Dourados, Mato Grosso do Sul, Brazil; E-mail: isaiasagraer@gmail.com (I. O.); cassiaagraer@gmail.com (C. R. Y. I. V.)

²Programa de Pós-Graduação em Entomologia e Conservação da Biodiversidade, Universidade Federal da Grande Dourados, Dourados, Mato Grosso do Sul, Brazil; E-mail: uchoa.manoel@gmail.com (M. A. U.); marcosfernandes@ufgd.edu.br (M. G. F.)

³Universidade Estadual de Mato Grosso do Sul, Dourados, Mato Grosso do Sul, Brazil; E-mail: odival@comp.uems.br (O. F.)

⁴Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados, Dourados, Mato Grosso do Sul, Brazil; E-mail: inessatorres@gmail.com (I. S. T. O.)

*Corresponding author; E-mail: uchoa.manoel@gmail.com

The guava crop, *Psidium guajava* L. (Myrtaceae), despite its growing economic importance in Brazil (Pereira et al. 2017), has productivity reduced due principally to the occurrence of some key pests (Souza Filho & Costa 2003), such as the triozid *Triozoida limbata* (Enderlein) (Hemiptera: Triozidae) (Burckhardt & Queiroz 2012; Sá & Fernandes 2015; Queiroz et al. 2018).

Triozoid limbata immatures wrap the margins of the guava leaves forming something similar to galls, where they are found; they principally use the shoots (Queiroz et al. 2018). The attack intensity of this species to guava is favored by mild temperatures (18 to 20 °C) and a shorter photoperiod (10 to 11 h of light) (Martins 2008).

The presence of *T. limbata* occurs on new shoots in conventional orchards, favoring their occurrence yr round (Melo et al. 2009). However, the highest population densities of adults in semi-organic orchards occur during spring and summer (Duarte et al. 2015).

The main control tactic for *T. limbata* in guava is the use of chemical pesticides. According to Pazini & Galli (2011), the only insecticide registered to control *T. limbata* is imidacloprid. The use of guava cultivars less susceptible to attack by *T. limbata* should be explored in the integrated pest management programs of guava crops.

Plants naturally have a certain degree of insect resistance, and for many yr biosynthesis, and regulation of plant chemical compounds associated with these defenses has been studied. Defensive substances are found in various plant tissues; among these compounds are antibiotics, alkaloids, terpenes, and proteins. Among the proteins are enzymes such as chitinases, lectins, and inhibitors of digestive enzymes (Ryan 1990).

Varietal resistance is a phenomenon related to the insect-plant interaction, and can be examined or defined from the point of view of one or both of the interacting agents (Painter 1951). Resistant plants negatively affect the reproductive potential, survival, and development of phytophagous insects, restricting their abundance (São João & Raga 2016). The relationship between the genetic variation of plants and environmental factors act to develop mechanisms of resistance to the attack of herbivores (Aoyama & Labinas 2012). On the other hand, herbivores also evolve to adapt and break these resistance mechanisms (Mauricio et al. 1997), which are expressed by plants as constitutive defense and induced defense, with direct or indirect action on herbivorous arthropods (Aoyama & Labinas 2012, São João & Raga 2016).

The plants present 2 basic mechanisms of defense against herbivory: constitutive defense and induced defense. The former is represented by chemical compounds and morphological structures that hinder herbivorous access to plants, and may affect some parameters of the biological cycle, such as the development and reproduction of insects. The second refers to morphological or physiological changes resulting from insect actions upon plants, causing a non-preference (antixenosis) of such insects for such plant varieties. The principal physiological changes of plants to resist herbivores are the reduction of their nutritional quality (Coley & Barone 1996; Aoyama & Labinas 2012; São João & Raga 2016).

The process of co-evolution between plants and insects constitutes a system of dynamic interactions. Plant chemical compounds, such as attractants, feed stimulants, repellents, deterrents, hormone sources, pheromones, and kairomones, are involved in various metabolic and behavioral processes of insects (Lovatto et al. 2012).

The plants present several forms of defense (resistance) to the attack of pests. Three types of plant resistance to insects are reported: antixenosis (non-preference), antibiosis, and tolerance. Antixenosis is the response of an insect, involving behavioral processes that result in avoiding certain plants as food or as a substrate for oviposition. Antibiosis occurs when the insect feeds normally from the plant, but this has an adverse effect on its biology. Tolerance is defined as the plant's own

ability to withstand or recover from damage produced by an insect population, which would normally cause serious damage to a more susceptible host (Painter 1951; Kogan & Ortman 1978; Lara 1991).

There is a lack of information on the evaluation of strategies for population monitoring and control of *T. limbata*. There are several cultivars of *P. guajava* in Brazil. With the intense process of breeding of this species, the cultivars become very different among themselves: canopy format, productivity, production time (early, mid-season, and late), number, size and shape of fruit, pulp color, post-harvest shelf life, and resistance to pests and diseases (Fumis & Sampaio 2011; Pommer et al. 2012). This can affect the behavior of insects, among them *T. limbata*, principally regarding its colonization in the guava tree. Our hypothesis is that some cultivars of *P. guajava* present resistance against the triozid.

Considering the lack of information essential to the selection of strategies for population monitoring and control of *T. limbata*, this research evaluated their preference for accessions in guava cultivars, evaluated the incidence of their nymphs and adults among the positions of the branches in the plants, and detected less susceptible varieties.

Materials and Methods

STUDY AREA

The evaluations were carried out in an experimental orchard of guava at Embrapa Agropecuária Oeste, Dourados, Mato Grosso do Sul, Brazil (22.277847°S, 54.818502°W; 430 masl) during the period of May 2013 to Jul 2014. The local climate is Cwa type (humid mesothermal climate, warm rainy summers and dry winters), Jun and Jul having low temperatures (< 18 °C), and Jan the hottest month (> 22 °C) (Fietz & Fisch 2008). The soil is characterized as dystrophic purple latosol (Ker 1997).

The sample area comprised 0.4 ha with 8 cultivars of *P. guajava* distributed in 4 blocks with 3 plants of each cultivar in sequence. The plant spacing is 7 m × 5 m, and the cultivars evaluated were 'Pedro Sato,' 'Kumagai,' 'Paluma,' 'Cascuda,' 'Século XXI,' 'Sassaoka,' 'Novo Milênio,' and 'Tailandesa.' At the beginning of this study, the plants were in the first cycle of fruiting (2 yr old).

Samplings were biweekly, quantifying the number of nymphs and adults of *T. limbata* in guava trees, presents in the upper third of the trees from the apex to the second pair of fully expanded leaves. We examined 3 leaves randomly per main branches, 4 branches per tree (between plants and between streets). We evaluated 96 plants in the area used, sampling 4 branches from each plant, and 12 leaves per plant, totalizing 1,152 leaves (by visual count or direct method).

Each plant was also monitored with a yellow adhesive trap (10 × 15 cm) fixed at the height of the canopy approximately 1.5 m above ground level (indirect method). These traps were placed in the same guava orchard evaluated by the direct method, and were exchanged every 2 wk. Then, traps were wrapped with transparent PVC film, packed in a plastic paste for subsequent quantification of the captured individuals. The counts were performed at the Laboratório de Insetos Frugívoros, Universidade Federal da Grande Dourados, Dourados, Mato Grosso do Sul, Brazil.

Management Practices in the Orchard

During the sampling period, routine cultural treatments were applied on the entire sampling area on the same date for all treatments, such as fertilization, control of invasive plants with mechanized brush-

cutter, pruning for fruit production, and application of fungicides and insecticides when pathogens or pests reached the control level. Irrigation was through a micro sprinkler.

Fertilization occurred from Sep to Dec 2013, and Jan 2014, in a total of 9 applications. Six fungicide applications were made between Oct and Nov 2013 and May 2014. Twelve applications of insecticides were made from Oct 2013 to May 2014, aiming at the control of insect pests, particularly: defoliating, fruit flies and other phytophagous insects.

Experimental Design and Statistical Analysis

The design was in a completely randomized block, consisting of 8 treatments (8 cultivars) and 4 replications, with a sample size of 3 plants. For statistical analysis of the data, we used a controlled experimental design in the field. To reach the proposed objectives, 2 assays were prepared.

Assay I. The objective of this study was to determine if there are more attractive cultivars for the trioqid (immatures and adults) through direct sampling in branches and indirect sampling with yellow traps.

The design of the first sampling consisted of the evaluation of each cultivar consisting of 4 plots with sets of 3 guava trees per cultivar, with observation made in the longitudinal and transverse positions. For the total number of immatures and adults quantified in the 4 plots of plants, the procedure was repeated 32 times, totaling 256 replicate samples for each cultivar.

For the second sample design, 96 yellow adhesive traps were installed to intercept the adults of *T. limbata* in flight. The sample design consisted of 8 cultivars, each cultivar represented by 4 plots (3 plants of each cultivar), adding 12 traps for each cultivar. This procedure was repeated 30 times, totaling 120 replicate samples for each cultivar.

Assay II. The objective of this study was to determine if the incidence of *T. limbata* (immatures and adults) in branches is equal between the positions. The design of this sampling consisted of 8 cultivars and 2 positions: longitudinal lines between plants (Q1–2), and transverse columns between streets (Q3–4). Each position consisted of the sum of 2 consecutive quadrants (Q1–2 = East–West, Q3–4 = South–North). For this evaluation the total number of immatures and adults quantified was as described in Assay I.

In both experiments, before applying the analysis of variance and multiple comparison tests, it was determined whether the assumptions of normality (Kolmogorov-Smirnov) and homogeneity (Levene) required in parametric models were attended by the variables measured. Because these pre-assumptions and independence within and

between the variables were not met, Kruskal-Wallis nonparametric statistical tests were used to determine the variance analysis, and the Dunn-Bonferroni bilateral test was used to make the paired comparisons.

All the results were analyzed considering the level of significance $\alpha = 5\%$. The values were processed in the SPSS Predictive Analytics Software, version 21 (IBM Corp., Armonk, New York, USA) by Odival Faccenda at Universidade Estadual de Mato Grosso do Sul, Dourados, Mato Grosso do Sul, Brazil.

Results

INCIDENCE OF IMMATURES AND ADULTS OF *TRIOZOIDA LIMBATA* ON PLANTS OF 8 GUAVA CULTIVARS (DIRECT SAMPLING)

The number of trioqid immatures in the branches of the 8 guava cultivars ($n = 256$) presented a significant difference. The lowest incidence of *T. limbata* occurred in 'Cascuda' and 'Kumagai' cultivars. On the other hand, the cultivars 'Tailandesa', 'Paluma', 'Pedro Sato', and 'Novo Milênio' had the highest levels of infestation by *T. limbata*. The cultivars 'Sassaoka' and 'Século XXI' formed an intermediate group for the levels of infestation without statistical significance between them (Table 1).

The cultivar 'Sassaoka' presented the lowest mean for adults of *T. limbata* in their branches. The largest adult population was obtained in 'Paluma', because in the other cultivars the differences were not significant. It is important to highlight that the differences between 'Paluma' and 'Kumagai' ($P = 0.051$), 'Paluma' and 'Pedro Sato' ($P = 0.076$), and 'Paluma' and 'Novo Milênio' ($P = 0.137$) were marginally significant (Table 1).

INCIDENCE OF ADULT *TRIOZOIDA LIMBATA* ON PLANTS OF 8 GUAVA CULTIVARS IN YELLOW TRAPS (INDIRECT SAMPLING)

The cultivars 'Cascuda', 'Kumagai', and 'Sassaoka' had the lowest mean number of adult *T. limbata* compared to the 'Paluma' cultivar. The latter had the highest mean number of individuals. The cultivars 'Tailandesa', 'Pedro Sato', 'Novo Milênio', and 'Século XXI' are an intermediate group that did not differ among themselves. The high values of the standard deviation were due to the distinct preference or rejection of *T. limbata* to the different cultivars (Table 2).

Table 1. Antixenosis of nymphs and adults of *Triozoida limbata* (Hemiptera: Triozidae) evaluated by direct method in 8 different cultivars of guava, *Psidium guajava* L. (Myrtaceae), Dourados, Mato Grosso do Sul, Brazil (May 2013 to Jul 2014).

Nymphs and adults of the trioqid, evaluated by direct method in guava cultivars									
Cultivars	Nymphs				Cultivars	Adults			
	NN	Averages	SD	MC		NA	Averages	SD	MC
'Cascuda'	5123	20.01	81.780	a	'Sassaoka'	1015	3.96	9.105	a
'Kumagai'	6090	23.79	85.666	a	'Pedro Sato'	1030	4.02	9.660	ab
'Tailandesa'	12016	46.94	154.488	b	'Novo Milênio'	1196	4.67	10.015	ab
'Sassaoka'	16541	64.61	189.078	ab	'Kumagai'	1388	5.42	12.787	ab
'Século XXI'	17152	67.00	261.521	ab	'Tailandesa'	1397	5.46	10.966	ab
'Paluma'	18055	70.53	241.750	b	'Século XXI'	1477	5.77	12.764	ab
'Pedro Sato'	21491	83.95	262.369	b	'Cascuda'	1574	6.15	13.990	ab
'Novo Milênio'	27736	108.34	331.923	b	'Paluma'	1634	6.38	10.923	b

Legend: NN = number of nymphs; NA = number of adults; SD = standard deviation; MC = multiple comparisons. The distribution of nymphs and adults of *Triozoida limbata* in branches followed by the same lowercase letter in the column of the multiple comparisons indicates that there was no difference between the distributions in these cultivars (Dunn-Bonferroni bilateral test; $P > 0.05$, $n = 256$).

Table 2. Antixenosis of adults of *Triozoida limbata* (Hemiptera: Triozidae) evaluated by indirect method in guava cultivars, *Psidium guajava* L. (Myrtaceae), municipality of Dourados, Mato Grosso do Sul, Brazil (May 2013 to Jul 2014).

Adults of <i>Triozoida limbata</i> caught in yellow traps				
Cultivars	Total of adults	Averages	Standard deviation	Multiple comparisons
'Cascuda'	15,859	132.16	298.662	a
'Kumagai'	22,478	187.31	417.764	a
'Sassaoka'	30,058	250.48	670.322	a
'Tailandesa'	33,522	279.35	656.327	ab
'Pedro Sato'	34,180	284.83	609.636	ab
'Novo Milênio'	34,811	290.09	698.666	ab
'Século XXI'	36,364	303.03	741.819	ab
'Paluma'	51,410	428.41	839.191	b

The distribution of *Triozoida limbata* adults caught in the traps followed by the same lowercase letter in the multiple comparisons column indicates no difference between the distributions in the cultivars by the Dunn-Bonferroni bilateral test ($P > 0.05$; $n = 120$).

TRIOZOIDA LIMBATA IN THE POSITIONS BETWEEN PLANTS AND BETWEEN STREETS OF DIFFERENT GUAVA CULTIVARS (DIRECT SAMPLING)

The levels of infestation by *T. limbata* were calculated in two positions: longitudinal and transversal, in the branches of 8 different guava cultivars. There were no differences in the distribution of immatures and adults of *T. limbata* between the positions of the branches on the plots (Table 3).

Discussion

Due to the fact that this research was conducted in an orchard under routine cultural practices (pruning, fertilization, and pesticide applications), no correlation with weather data was tested because the experiment should be free of cultural practices to isolate the effects of abiotic factors.

There was an increase in triozid abundance during the sample period, regardless of climatic variations. In this context, the results of the publications that correlated populations of *T. limbata* with weather data are conflicting. Several papers published in Brazil report this conflict in relation to the influence of weather. Some studies conclude that there is influence of temperature on the population density of the triozid, both in the 'Paluma' cultivar (Colombi & Galli 2009) and in native guava trees (Dalberto et al. 2004). On the other hand, other studies report the absence of temperature and rainfall effects on the populations of *T. limbata* adults in orchards with a collection of guava

genotypes (92 cultivars) (Duarte et al. 2015), and in orchards with the cultivar 'Paluma' (Pazini & Galli 2011).

Scientific publications widely report that the climatic factors affect the abundance of the triozid. According to Queiroz et al. (2018), *T. limbata* is restricted to Central and South America, although guava is currently cultivated in several warm regions around the world. These authors, through the modeling of potential distributions based on distributive data from the Americas, have inferred that the effects of global climate change will be more evident in the east and northeast of Brazil, where there will be an increase in the concentration of this pest species exerting more pressure on the production of guava, and increasing the potential for damage induced by the guava's triozid.

During the sampling period of this research, large temperature variations occurred (−0.7 to 35.8 °C). The beginning of sampling coincided with the low and high temperature periods, and with the pruning and opening of the 4 main branches of each plant to for the first yr of fruiting. The females of *T. limbata* lay their eggs along branches, new shoots, and new leaves (Nakano & Silveira Neto 1968). Due to this behavior, there were few immatures at the beginning of the sampling period because to a lack of new leaves in the plants, as a consequence of the pruning to induce flowering and fruiting. This fact was expected, because it is known that the weather influences insect population densities (Huffaker & Gutierrez 1999).

The pruning to induce fruiting of the plants was carried out between 9 and 20 September 2013. After this period, there was an increase in the *T. limbata* population density, constantly reaching the control level, generating the need to perform several actions for population suppression. However, after Apr 2014 (the 21st evaluation), control actions were no longer necessary due to the beginning of fruit harvest. In contrast to the previous yr, after harvesting there was neither fruit pruning nor a marked drop in temperature, which led to the rapid development of tree canopies, increasing the availability of new leaves, and promoting rapid growth of the *T. limbata* population. This shows that the abundance of herbivorous insects is affected by both the availability of food resources (Pinheiro et al. 2002; Araújo 2013) and the weather (Wolda 1988).

The occurrence of insect pests is among the factors that most influence the productivity of agricultural crops, because they directly consume parts of plants and can transmit diseases. Therefore, it is expected that when plants are well-nourished (adequate fertilization), they better tolerate pest attack (Bianchini et al. 2015). However, the effect of fertilization on the production of the 8 cultivars was not evaluated, but the spatial distribution of *T. limbata* in the evaluated cultivars was studied. This triozid presented aggregate behavior, demonstrating preference for some guava cultivars. According to Bianchini et al. (2015), the effect of plant fertilization on pest incidence often is not

Table 3. Population distribution of nymphs and adults of *Triozoida limbata* (Hemiptera: Triozidae) in the branches of *Psidium guajava* L. (Myrtaceae) from 8 different cultivars, i.e., Longitudinal, between plants (East-West), versus Transverse, between streets (South-North); trees 2 yr old in an orchard in the municipality of Dourados, Mato Grosso do Sul, Brazil (May 2013 to Jul 2014).

Position	Nymphs				Adults			
	NN	Averages	SD	MC	NA	Averages	SD	MC
Longitudinal	65,547	64.01	225.41	a	5,694	5.56	11.973	a
Transversal	58,655	57.29	212.85	a	5,018	4.90	10.803	a

NN = number of nymphs; NA = number of adults; SD = standard deviation; MC = multiple comparisons. The distribution of nymphs and adults of *Triozoida limbata* followed by the same lowercase letter in the multiple comparisons column indicates that there was no significant difference between the distributions in the cultivars (Dunn-Bonferroni bilateral test; $P > 0.05$, $n = 1024$).

significant, but there is an effect on the plant that is better nourished, making it more tolerant to herbivores.

Plant species generally exhibit a certain degree of resistance to herbivorous insects (Ryan 1990). These also present defenses that can affect the growth and development of insects through toxic secondary metabolites (War et al. 2018). It is equally important to understand insect-pest adaptations to these defensive characteristics in order to develop and deploy management strategies to suppress insect pest populations (War et al. 2018). Preferences of insect pests to host plants often can be modified by experience and conditioning (Barron 2001; Santa-Cecilia et al. 2013). It is likely that the adult females of *T. limbata* define which plants will receive their offspring, because we observed the preference of adults for certain cultivars. As described by Painter (1951), when insect females are caged in resistant plants they deposit fewer eggs than females caged in plants of susceptible varieties.

Susceptible guava cultivars may offer better conditions for *T. limbata* to develop and reach adulthood. On the other hand, in resistant plants this species has difficulty in establishing. Such plants generally negatively affect the biology of insect pests (Gould 1998) because physiological changes in the induced defense mechanism of plants, such as antixenosis or non-preference, or also a decrease in the nutritional quality for their herbivores may occur. Thus, resistant plants may offer fewer resources to the herbivore than susceptible ones (Aoyama & Labinas 2012). In response to pest attack, they can activate defensive genes which lead to the production of physical barriers or synthesis of chemical compounds that may prevent or reduce the feeding of phytophagous insects (Guerrieri & Digilio 2008).

As phytophagous insects require adequate habitat for the development of their offspring, host plants are essential to provide water, nutrients, shelters, mating sites, and oviposition, among other pre-requisites (Edwards & Wratten 1981). In this sense, *T. limbata* probably co-evolved in this interaction, selecting its host plants. Ouvrard et al. (2015) have highlighted the ability of Psylloidea to adapt to host plants probably depends on their ability to deal with a complex set of biochemical defenses. On the other hand, Rossiter (1996) pointed out that it is difficult to determine if differences in the levels of preference observed in the field have a genetic basis, or are the result of intervening factors, such as temperature, plant nutrition, conditioning, and adaptation inheritance to the environmental effects. But the impact of inherited environmental effects on offspring may be positive or negative, depending on the nature of the contribution and the ecological context in which the offspring exist.

Our results show that immature as well as adults of *T. limbata* present antixenosis to 'Kumagai' and 'Cascuda' cultivars. The quantification of *T. limbata* populations in situ (direct sampling) and the use of adhesive traps (indirect sampling) showed the same efficiency to evaluate infestation levels in the different guava cultivars tested, as well as in the detection of the levels of damage. However, in situ we recorded the adults on the plants only at the evaluation intervals (from 7:00 A.M. to 9:00 A.M.), whereas for adults caught in traps this period extended to full time (15 d), beyond the fact that adults are also attracted by color. Thus, it was verified that indirect sampling was adequate to demonstrate the antixenosis (sensu Kogan & Ortman 1978) of adults in 'Cascuda' and 'Kumagai' cultivars. The direct sampling showed that the number of immatures in these 2 cultivars differs from the others. In this context it is considered that the adults (indirect sampling) avoided these cultivars, both for feeding and for oviposition.

From the results obtained in this study, it should be clear that the preference of immatures (sensu Burckhardt et al. 2014) and adults of *T. limbata* is for the 'Paluma' guava cultivar. This fact can be explained, at least in part, by the behavioral response of this trioqid to the charac-

teristics of the host plant. This cultivar, which produces fruits destined for consumption *in natura* and industrialization, presented the higher populations of *T. limbata*. The high populations of immatures, which are responsible for the hard damage levels in guava orchards (Semeão 2006) are easily visualized in the new leaves.

In this study, *T. limbata* presented distinct preference for the different evaluated guava cultivars, due to the low levels of infestations observed in some cultivars. The cultivars less susceptible to the attack of *T. limbata* immatures and adults, were 'Cascuda' and 'Kumagai.' Therefore, both are promising cultivars for guava breeding programs, aiming at the resistance of *P. guajava* to the attack of *T. limbata*. This discovery is of great importance for genetic improvement programs on guava trees, aiming to incorporate resistance to control the guavas's trioqid in commercial cultivars. Our results contribute to the integrated management of guava pests, making it possible to reduce the use of pesticides and the cost of production and, consequently, environmental impact and intoxication in humans.

The fact that there is no significant difference in the number of immatures and adults among plant or between streets, as verified in this research, allows producers and technicians to save time and money for population monitoring of *T. limbata* in the field. Thus, in order to carry out sampling, there will be no concern as to which of the main branches (among the 4 that leave the trunk) of the plant should have its new leaves sampled. There are no differences in levels of infestation by immature and adult *T. limbata* in the different guava tree branches, as pointed out by Moreira (2005). Therefore, in *P. guajava*, for sampling of *T. limbata* in the field, new leaves from any of the 4 main branches can be evaluated and will allow the detection of their occurrence, and of their population density in the orchards.

Acknowledgments

We thank Dalva Luiz de Queiroz (Embrapa Florestas, Colombo-PR, Brazil) for the identification of *Trioizoida limbata*, and the following institutions for the financial support: CNPq-Conselho Nacional de Desenvolvimento Científico e Tecnológico for the grant (Processo: 305112/2012-0) based on research productivity to M. A. Uchoa; Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul (FUNDECT)-CAPES-Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Chamada N°. 44/2014 PAPOS-MS), FUNDECT-CAPES (Edital N°. 12/2015-BIOTA-MS-Ciência e Biodiversidade), and Universidade Federal da Grande Dourados (UFGD).

References Cited

- Aoyama EM, Labinas AM. 2012. Características estruturais das plantas contra a herbivoria por insetos. Enciclopédia Biosfera, Centro Científico Conhecer, Goiânia 8: 365–386.
- Araújo WS. 2013. A importância de fatores temporais para a distribuição de insetos herbívoros em sistemas Neotrópicos. Revista da Biologia 10: 1–7.
- Barron AB. 2001. The life and death of Hopkins' host-selection principle. Journal of Insect Behavior 14: 725–737.
- Bianchini RA, Pissinato TR, Campos AP, Moreira WMQ, Ramos MHC. 2015. Efeitos da adubação de plantas no manejo de pragas. Revista Fafibe On-Line 8: 108–120.
- Burckhardt D, Ouvrard D, Queiroz DL, Percy DM. 2014. Psyllid host-plants (Hemiptera: Psylloidea): resolving a semantic problem. Florida Entomologist 97: 242–246.
- Burckhardt D, Queiroz DL. 2012. Checklist and comments on the jumping plant-lice (Hemiptera: Psylloidea) from Brazil. Zootaxa 3571: 26–48.
- Coley PD, Barone JA. 1996. Herbivory and plant defenses in tropical forests. Annual Review of Ecology and Systematics 27: 305–335.

- Colombi CA, Galli JC. 2009. Dinâmica populacional e evolução de dano de *Triozoida limbata* (Hemiptera: Psyllidae) em goiabeira, em Jaboticabal, SP. *Ciência e Agrotecnologia* 33: 412–416.
- Dalberto FMS, Menezes Jr AO, Simões HC, Benito NP, Pitwak J. 2004. Flutuação populacional do psílideo-da-goiabeira, *Triozoida limbata* (Hemiptera: Psyllidae) na região de Londrina, PR. *Semina: Ciências Agrárias* 25: 87–92.
- Duarte RT, Baptista APM, Pazini WC, Galli JC. 2015. Flutuação populacional de *Triozoida limbata* Enderlein (Hemiptera: Trioizidae) e de *Scymnus* spp. (Coleoptera: Coccinellidae) em pomar de goiaba (*Psidium guajava* L.). *Scientia Agraria Paranaensis* 14: 173–177.
- Edwards PJ, Wratten SD. 1981. *Ecologia das Interações entre Insetos e Plantas*. E.P.U/EDUSP, São Paulo, São Paulo, Brazil.
- Fietz CR, Fisch GF. 2008. O clima na região de Dourados, MS. 2nd edition. Embrapa Agropecuária Oeste, Dourados, Mato Grosso do Sul, Brazil.
- Fumis TF, Sampaio AC. 2011. *Biologia e cultivares*. pp. 1–11. In Sampaio AC [ed.], *Goiaba: do Plantio à Comercialização*. CATI, Campinas, São Paulo, Brazil.
- Gould F. 1998. Sustainability of transgenic insecticidal cultivars: integrating pest genetics and ecology. *Annual Review of Entomology* 43: 701–726.
- Guerrieri E, Digilio MC. 2008. Aphid-plant interactions: a review. *Journal of Plant Interactions* 3: 223–232.
- Huffaker CB, Gutierrez AP. 1999. *Ecological Entomology*, 2nd edition. Wiley, New York, USA.
- Ker JC. 1997. Latossolos do Brasil: uma revisão. *Geonomos* 5: 17–40.
- Kogan M, Ortman EF. 1978. Antixenosis - a new term proposed to define Painter's "nonpreference" modality of resistance. *ESA Bulletin* 24: 175–176.
- Lara FM. 1991. *Princípios de Resistência de Plantas a Insetos*. 2nd edition. Editora Ícone, São Paulo, São Paulo, Brazil.
- Lovatto PB, Schiedeck G, Garcia FRM. 2012. A interação co-evolutiva entre insetos e plantas como estratégia ao manejo agroecológico em agroecossistemas sustentáveis. *Interciência* 37: 657–663.
- Martins JC. 2008. *Variação sazonal de Triozoida limbata* (Hemiptera: Trioizidae) e inimigos naturais em goiabeira. Dissertação (Mestrado em Entomologia), Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil.
- Mauricio R, Rausher MD, Burdick DS. 1997. Variation in the defense strategies of plants: are resistance and tolerance mutually exclusive? *Ecology* 78: 1301–1311.
- Melo G, Costa VA, Soares Júnior H, Souza-Filho MF, Ramiro ZA, Sato ME. 2009. Dinâmica populacional de *Triozoida limbata* (Hemiptera: Trioizidae) em pomar convencional e orgânico de goiaba na região de Campinas, SP. III Simpósio Brasileiro da Cultura da Goiaba, 29 de setembro a 02 de outubro de 2009. Campinas, São Paulo, Brazil.
- Moreira MD. 2005. *Sistemas de tomada de decisão de controle para Triozoida sp.* (Hemiptera: Sternorrhyncha: Psyllidae) em goiabeira. Tese (Doutorado em Entomologia), Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil.
- Nakano O, Silveira Neto S. 1968. Contribuição ao estudo da *Triozoida* sp. near johnsonii Crawl., praga da goiabeira. *Ciência e Cultura* 20: 263–264.
- Ouvard D, Chalise P, Percy DM. 2015. Host-plant leaps versus host-plant shuffle: a global survey reveals contrasting patterns in an oligophagous insect group (Hemiptera, Psylloidea). *Systematics and Biodiversity* 13: 434–454.
- Painter RH. 1951. *Insect Resistance in Crop Plants*. The University Press of Kansas, Lawrence, Kansas, USA.
- Pazini WC, Galli JC. 2011. Redução de aplicações de inseticidas através da adoção de táticas de manejo integrado do *Triozoida limbata* (Enderlein, 1918) (Hemiptera: Trioizidae) em goiabeira. *Revista Brasileira de Fruticultura* 33: 66–72.
- Pereira FM, Usman M, Mayer NA, Nachtigal JC, Maphanga ORM, Willemse S. 2017. Advances in guava propagation. *Revista Brasileira de Fruticultura* 39: 1–24.
- Pinheiro F, Diniz IR, Coelho D, Bandeira MPS. 2002. Seasonal pattern of insect abundance in the Brazilian cerrado. *Austral Ecology* 27: 132–136.
- Pommer CV, Oliveira OF, Santos CAF. 2012. *Goiaba: recursos genéticos e melhoramento*. EdUFERS, Mossoró, Rio Grande do Norte, Brazil.
- Queiroz DL, Wrege MS, Künast TBS, Garrastazu MC, Burckhardt D. 2018. Potential distribution of the guava psyllid *Triozoida limbata* (Hemiptera, Psylloidea), today and in global climate change scenarios. *Turkish Journal of Zoology* 42: 330–336.
- Rossiter MC. 1996. Incidence and consequences of inherited environmental effects. *Annual Review of Ecology and Systematics* 27: 451–476.
- Ryan CA. 1990. Protease inhibitors in plants: genes for improving defenses against insects and pathogens. *Annual Review of Phytopathology* 28: 425–449.
- Santa-Cecília LVC, Prado E, Oliveira MS. 2013. Sobre o condicionamento alimentar na cochonilha-branca, *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae). *Revista Brasileira de Fruticultura* 35: 86–92.
- Sá VA, Fernandes MG. 2015. Spatial distribution of nymphs of *Triozoida limbata* Enderlein, 1918 (Hemiptera: Trioizidae) in guava orchards. *Journal of Agricultural Science* 7: 41–54.
- São João RE, Raga A. 2016. Mecanismo de defesa das plantas contra o ataque de insetos sugadores. Documento Técnico 23. ISSN 1983-134X. Agência Paulista de Tecnologia dos Agronegócios (APTA). Instituto Biológico-APTA, Campinas, São Paulo, Brazil.
- Semeão AA. 2006. *Controle natural de Triozoida limbata* em goiabeira. Dissertação (Mestrado em Entomologia), Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil.
- Souza Filho MF, Costa VA. 2003. Manejo integrado de pragas da goiabeira. In Rozane DE, Couto FAA [eds.], *Cultura da Goiabeira: Tecnologia e Mercado*. Suprema Gráfica e Editora, Visconde do Rio Branco, Minas Gerais, Brazil.
- Wolda H. 1988. Insect seasonality: why? *Annual Review of Ecology and Systematics* 19: 1–18.
- War AR, Taggar GK, Hussain B, Taggar MS, Nair RM, Sharma HC. 2018. Plant defence against herbivory and insect adaptations. *AoB Plants* 10: 1–9.