Hindawi Publishing Corporation
Psyche
Volume 2010, Article ID 819532, 4 pages
doi:10.1155/2010/819532

Research Article

Fruit Damage Patterns Caused by Ovipositing Females of *Conotrachelus dimidiatus* (Coleoptera: Curculionidae) in Guava Trees

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Received 3 December 2009; Accepted 17 May 2010

Academic Editor: Abraham Hefetz

We evaluated the damage patterns produced by females of the guava weevil *Conotrachelus dimidiatus* Champion, 1904 (Coleoptera: Curculionidae), according to the position of the damaged fruit in guava trees *Psidium guajava* L. in Calvillo, Aguascalientes, Mexico. The trees were subdivided in eight zones, and during one year the level of fruit lesions due to oviposition was registered. Results showed a higher level of damage in the upper and external zone of the trees ($P \leq .05$). We found no significant differences in damage between the four cardinal points ($P \geq .05$). During the year, the level of damage was recorded and was higher in the months of August and September ($P \leq .05$) associated with rainfall (0.86, $P = .06$) and increase in temperature (0.84, $P = .03$). The most susceptible fruits were in the size range of 2.1–4.0 cm (polar diameter). The information from this study will be used to design and establish effective control strategies for the guava weevil, taking into account location of the most susceptible fruits, seasonality of the pest, and the abiotic factors.

1. Introduction

Guava *Psidium guajava* L. is a plant whose origin is tropical America, and is cultivated mainly for consumption as fresh fruit or for juices, jellies, or marmalades. It contains vitamin A, C, iron, calcium, and phosphorus [1]. In Mexico, the national guava production averages 300, 613 tons over the past five years [2]. Other factors associated with the crop are low technological standards, saturated internal consumption market, incipient exportations and damage from insect pests [3].

For the municipality of Calvillo, Aguascalientes, and Juchipila, Zacatecas, various species of the genus *Conotrachelus* are reported to be associated with the guava crop. The guava weevil *Conotrachelus dimidiatus* Champion is considered to be the species that causes the most damage [4]. When the adults emerge from soil they fly towards the tree to feed on floral buds and tissues. After mating, the females oviposit preferably in the middle portion of green unripe fruits (2 cm diameter). Oviposition sites have a circular concave and cork-like appearance. Furthermore, the infected fruits develop prematurely and acquire a kidney shape that excludes them from commercialization. In a single season, the adult weevils can infest up to 70% of the cultivated orchards and cause losses of as much as 60% of production [4]. Until now chemical control has been predominant, which is applied when one weevil per tree is detected and the first fruits with oviposition are observed.

The damage pattern is the result of a variable behavior of the insects. This flexibility, according to the phenology of the crop and response to abiotic factors, increases the risk of damage. For example, for the bean borer *Cydia fabivora* Stansly and Sanchez [5] report a higher oviposition on the underside of the leaf prior to flowering (55%).

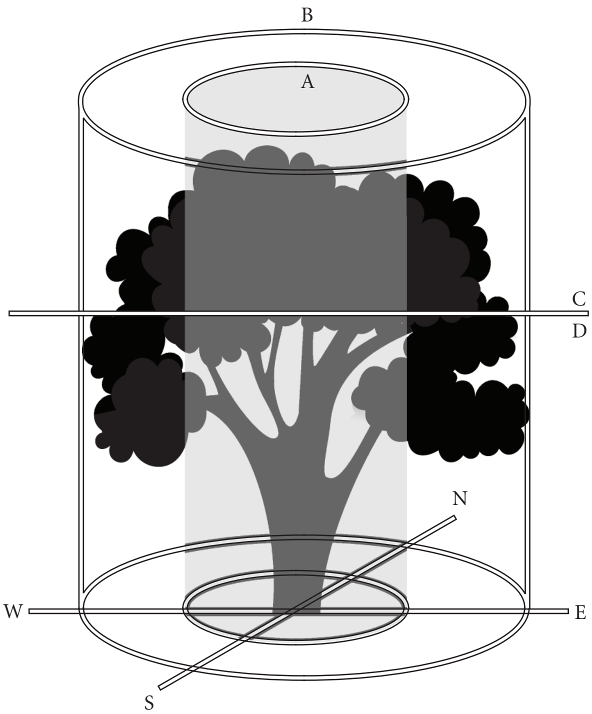

Figure 1: Division of the guava trees to determine the damage pattern of *Conotrachelus dimidiatus*. Internal zone (A) external zone (B). Upper zone (C) and lower zone (D). Cardinal points: North (N), South (S), East (E), and West (W).

Table 1: Average of damage from *Conotrachelus dimidiatus* in guava trees in Calvillo, Aguascalientes.

Plane	Sector	Mean oviposition ± SE	% damaged
Cardinal	North	0.78 ± 0.09a	27.02
	South	0.66 ± 0.08a	23.07
	East	0.66 ± 0.09a	23.07
	West	0.77 ± 0.08a	26.81
Radial	Interior	0.62 ± 0.09a	40.50
	Exterior	0.92 ± 0.07b	59.49
Horizontal	Superior	1.44 ± 0.19a	33.70
	Inferior	0.73 ± 0.13b	66.29

Means followed by the same letters inside planes were not significantly different (LSD, 0.05).

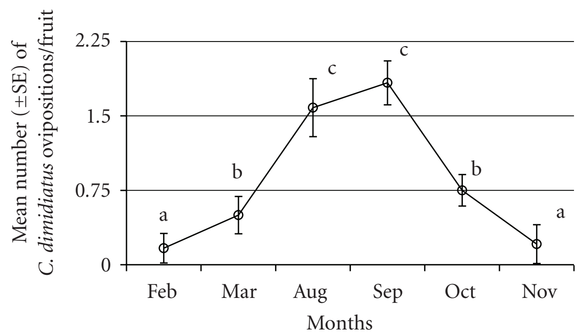

Figure 2: Temporal distribution of damage (±SE) by *C. dimidiatus* in guava trees in Aguascalientes, Mexico. Months with different letters are significantly different (LSD, 0.05).

However, when the pods emerge, they are preferred for oviposition (84%). A study of the biology pertaining to the oviposition of the beetle *Acanthocinus nodosus* reports a period of colonization of *Pinus taeda* with the totality of the ovipositions on the lower part of the trunk with an average of 3.3 eggs per hole [6]. By now the appearance of the oviposition of the guava weevil is well know [4, 7]; however, the pattern of ovipositions on the host and their distribution throughout the year are unknown. The objective of the present study was to establish the damage pattern of females of *C. dimidiatus* in different zones of guava trees, the distribution of damage throughout the year, the size of the most susceptible fruit, and the effect of abiotic factors.

2. Methods

This investigation was carried out from September of 2007 to September of 2008 in a leveled guava orchard (40 × 90 m) located in the municipality of Calvillo, Aguascalientes, Mexico (102° 43′W, 21° 51′ N) and 1667 m altitude. The plantation was of the Media China variety with 10 years of age and free of pesticide applications.

2.1. Determination of the Damage Pattern. To determine the damage pattern on the host, the trees were divided in eight zones and three planes: internal and external zone (radial plane), upper and lower (horizontal plane), and the four cardinal points (cardinal plane) (Figure 1). To determine the radial plane, the distance was measured from the trunk to the extreme end of the foliage, with the middle point being the external-internal division. For the horizontal plane, the total height of the tree was registered considering half of the height as the upper-lower division. With the help of a geopositioner (eTrex Summit; Garmin International), the four orientations of the cardinal plane were established. The distribution of damage on the fruits was registered throughout the year with samplings every fifteen days, where six different trees were randomly selected and their height determined. The damage pattern of the fruit was established by randomly selecting five fruits per sampling location of the eight established zones and registering the number of ovipositions per fruit. To establish the size of the most susceptible fruit, the polar diameter of each sampled fruit was determined with a Vernier caliper. The fruits remained on the tree after inspection.

2.2. Statistical analysis. For the evaluation of damage of the fruits in the trees, a completely randomized design was used with eight treatments (according to the zones) and six replicates. The averages of ovipositions per fruit and the total percentage of damaged fruit per zone of the trees were calculated. Means were square root transformed to stabilize the variances. To determine if there was a difference in the damage among the eight zones at a significance level of 5%, we conducted an analysis of variance and the Fisher protected least significant difference test (LSD) using the statistical package SAS [8]. The assumptions of the ANOVA were verified [9]. The Pearson coefficients of correlation were also calculated among the total damage and the variables of temperature, rainfall, and relative humidity for the period of study.

3. Results

In total 83 trees were sampled with an average height of 3.09 ± 0.3 m. The average of damage produced by *C. dimidiatus* significantly differed according to the zones of the tree (Table 1). Within the radial plane, the external zone had higher damage with respect to the internal zone ($F = 5.79$; $df = 1$; $P = .01$). For the horizontal plane, the upper portion presented statistically higher damage than the lower portion ($F = 9.43$; $df = 1$; $P = .002$). Although there were variations in the percentages of damage among the four cardinal points, no statistical difference occurred among them ($F = 0.48$; $df = 3$; $P = .69$).

3.1. Temporal Damage Pattern. The mean fruit damage showed highly significant differences dependent on the month of sampling ($F = 16.37$; $df = 5$; $P = .0001$). The first indications of damage were observed in February (4), which were similar to what was observed in November (5). A higher incidence occurred in March (21) and October (18) (Figure 2). The peak damage occurred between the months of August (38) and September (44), which is during the rainy season. There was a significant correlation between the amount of damage by *C. dimidiatus* and temperature (0.84, $P = .03$) for the zone of Calvillo, Aguascalientes. There was no significant correlation between damage and the rainfall (0.86, P = 0.06) or the relative humidity (0.72, $P = .1$).

In our study the highest number of ovipositions (32) occurred in fruits of 3.3 cm polar diameter with a susceptibility range between 2.1 and 4.0 cm polar diameter (Figure 3). Of the total of fruits counted (2626), 17.9% presented signs of ovipositions of *C. dimidiatus* in the Calvillo region, Aguascalientes during the year of study.

4. Discussion

The damage pattern to the fruits of the guava trees indicates that the guava weevil initiates colonization of the plants from the outside to the inside, perhaps by means of short flights from other trees or from weeds and not by weevils climbing through the trunk. After colonization, higher damage occurred in the upper and inside zone of the trees. According to reports of damage patterns in Curculionids, Piñero et al. [10] did not find significant differences in the damage caused by plum curculio between the internal and external zones in apple trees. As in our study, there is evidence of higher damage by *Conotrachelus nenuphar* in fruits of the upper [11] and middle portion [12] of apple trees. We believe that differences in damage pattern are also closely related with meticulous procedures to scout the trees. Although we found no significant differences in damage between the four cardinal points, Piñero et al. [10] found higher levels of damage on the west side of the trees, given that the adults occupy this orientation during sunset. The peak damage during the rainy season of *C. dimidiatus* in Mexico is also reported in Venezuela by Boscan and Casares [13] for adults of *Conotrachelus psidii* Marshall which are present in guava trees from March to August, with a maximum in the month of May.

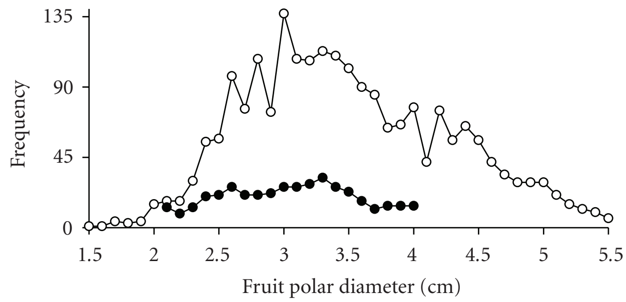

Figure 3: Distribution of damage (•) of *C. dimidiatus* with respect to polar diameter (○) in guava fruits in Aguascalientes, Mexico. Oviposition frequencies ≥ 10 are reported.

The appearance of the fruits damaged by ovipositions of *C. dimidiatus* was kidney shaped, with a cork-like concavity and early maturation. Gonzalez [4] mentions that oviposition occurs mainly in the middle portion of the fruit (72.3%) during the small fruit stage (2 cm diameter) which is similarly reported for *C. psidii* [14]. Kidney shape and premature abscission are caused by pectins. Levine and Hall [15] report several of these substances in plums and apples infested with plum curculio larvae *C. nenuphar* Herbst. We mostly found one oviposition per fruit, which indicated the presence of a signal compound in *C. dimidiatus* similar to natural antifeedants compounds reported in the feces of *Hylobius abietis* L. deposited adjacent to each egg, at which cavities were avoided by other pine weevils [16].

Although there was no significant correlation between the amount of damage and rainfall or relative humidity, Gonzalez [4] reported these abiotic factors as the cause of adult emergence. The capacity to remain in the soil after completed pupation also has been observed in *C. psidii* which can be underground for a further 34 ± 18 days under laboratory conditions [14]. All of this data indicates that abiotic factors need to be considered for guava weevil management.

According with our results of damage patterns and effect of abiotic factors, any control strategy for the adults, including pheromone traps, should be applied mainly in the upper and external portions of guava trees and there is no experimental evidence to apply pesticides during the rainy season. Following these directions, spraying a large amount of chemicals can be avoided. Additionally, low temperatures were a limitation for the presence of adults; therefore, control measures in the winter months are unnecessary.

Acknowledgments

The authors would like to express their thanks to Jose Carlos Ruvalcaba Camacho and Victor Manuel Ramirez Tapia for their assistance in the field work. This work received financial support from the Fondo Sectorial Sagarpa-Conacyt (registration code 2005-12161).

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