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MOTH SPECIES CAPTURED WITH THE SEX PHEROMONE OF *STENOMA CATENIFER* (LEPIDOPTERA: ELACHISTIDAE) IN AVOCADO PLANTATIONS OF SOUTHERN MEXICO

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Abstract

Moth species trapped using the sex pheromone of Stenoma catenifer (LaSalle) as a lure, were registered at 2 commercial avocado orchards (one consisting of "Hass" and other of "Criollo") and in wild "Criollo" avocado trees in southern Mexico. Traps were maintained for 1 mo in two seasons (dry and wet) on avocado trees under these 3 production conditions, changing the baits each season. Weekly observations registered no moths in the traps placed in the commercial "Hass" avocado orchard, in contrast to the other 2 sites, where Stenoma catenifer and Antaeotricha nictitans males were captured. Stenoma catenifer adults were always observed at the commercial "Criollo" orchard and wild "Criollo" avocado trees during the dry season (fructification period), but never in the wet season (non fruiting period). Under wild conditions A. nictitans was captured during both dry and wet seasons; however, it was never captured during the dry season at the commercial "Criollo" orchard. Populations of both moth species were similar -S. catenifer: 0.3 (wild trees) to 0.7 (orchard); and A. nictitans: 0.6 (wild trees) moth/trap/wk- during the dry season, and no differences were observed per species at each locality. The total number of captures per site during the fruiting season decreased significantly -0.9 (1st wk) to 0.2(4th wk) moth/trap/wk- during the observation period. S. catenifer was found infesting dropped fruit in the commercial "Criollo" orchard and at the wild site, whereas A. nictitans larvae were not detected infesting fruit. Captured S. catenifer males were always associated with the presence of avocado fruit in the field. The host of A. nictitans remains unknown.

Key Words: traps, avocado seed moth, Antaeotricha nictitans

Resumen

Las especies de palomillas atrapadas con la feromona sexual de Stenoma catenifer (LaSalle) como cebo, fueron registradas en 2 cultivos comerciales de aguacate (uno de "Hass" y el otro "Criollo") y en arboles silvestres de aguacate "Criollo" del sur de México. Las trampas fueron mantenidas en los cultivos por un mes en dos estaciones climáticas (seca y húmeda) en los arboles de aguacate, cambiando los cebos en cada estación. Mediante observaciones semanales no se registraron palomillas en las trampas ubicadas en el cultivo de aguacate comercial "Hass", en contraste con los otros 2 sitios, donde los machos de S. catenifer y Antaeotricha nictitans fueron capturados. Los adultos de S. catenifer fueron siempre capturados en el cultivo comercial "Criollo" y en los árboles silvestres de aguacate "Criollo" durante la estación seca (período de fructificación), pero nunca en la estación húmeda (período de no fructificación). Bajo condiciones silvestres A. nictitans fue capturada tanto en la estación seca, como en la húmeda; sin embargo, nunca fue capturada durante la estación seca en el cultivo comercial de aguacate criollo. Las poblaciones de ambas especies de palomillas fueron similares - S. catenifer: 0.3 (árboles silvestres) a 0.7 (cultivo); y A. nictitans: 0.6 (árboles silvestres) palomillas/trampa/semana- durante la estación seca, y no se observaron diferencias por especie en cada localidad. El número total de capturas por sitio durante la estación de fructificación disminuyó significativamente - 0.9 (1^{ra} semana) a 0.2 (4^{ta} semana) palomillas/trampa/semana - durante el período de observación. S. catenifer fue encontrada infestando a los frutos caídos en el huerto comercial "Criollo" y en sitio silvestre, mientras que las larvas de A. nictitans no fueron detectadas infestando frutos. La captura de machos de S. catenifer fue asociada con la presencia del fruto de aguacate en las localidades. El hospedero de A. nictitans permanece desconocido.

Palabras clave: trampas, palomilla de la semilla de aguacate, Antaeotricha nictitans

Stenoma catenifer Walsingham (Lepidoptera: Elachistidae) is one of the most important avocado (Persea americana Miller; Laurales: Lauraceae) pests in the new world. This pest is distributed in several regions of Mexico, as well as in some countries of Central and South America (Walsingham 1909). Stenoma catenifer was first recorded from the highlands of Guatemala (Walsingham 1909; Busck 1919). In Mexico, S. catenifer has been recorded in Chiapas, Colima, Guerrero, Nuevo León, Oaxaca, Tamaulipas, Veracruz and Querétaro (Acevedo 1972; Palacios-Torres et al. 2011), without geographical reference points in most cases. Stenoma catenifer prefers to attack the fruit, but its larvae can also be found in galleries on branches and stems of avocado trees (Hoddle & Hoddle 2008).

A sex pheromone ([9Z]-9,13-tetradecadien-11-ynal) (Millar et al. 2008) has been used to detect males of S. catenifer in southern Mexico and Guatemala during the avocado fruiting period (Hoddle et al. 2009; Hoddle et al. 2011). Antaeotricha nictitans (Zeller) (Lepidoptera: Elachistidae: Stenomatinae) has also been captured using this pheromone with a frequency 7-9 times higher than S. catenifer, and could be an unknown avocado pest (Hoddle et al. 2011). Therefore, the aim of this study was to identify the variability of moth species captured with the sex pheromone of S. catenifer in 2 periods of the year at 3 sites from the Mesoamerican origin zone of the avocado in Mexico. Determining the seasonal attractiveness of the sex attractant pheromone of S. catenifer would contribute to the search for an effective and selective lure to monitor the presence of this pest during different seasons, and also help us to understand the association of A. nictitans with the avocado crop.

MATERIAL AND METHODS

Field Sites

Experiments were carried out at 3 sites, each with different agroecological conditions, in the Soconusco region, Chiapas, Mexico. In this region, a marked dry season occurs between Dec-May, resulting in a very short avocado fruiting period (Jan-May). One 'Hass' and one 'Criollo' orchard and a set of uncultivated 'Criollo' avocado trees were used to evaluate the attractiveness of the sex pheromone of S. catenifer to male moths in 2 climatic seasons. "El Carmen" (N 15° 02' 4.3' W 92° 09' 45.2'; 650 m asl) in the municipality of Cacahoatan is a 3-ha non-producing orchard of seventy 2-4 m high 'Hass' trees of which 69 were non-bearing and 1 was bearing a few fruits. "La Soledad" (N 15° 00' 57.6' W 92° 10' 39.7'; 560 m asl), is a 10-ha orchard with 100 "Criollo" avocado trees (4-5 m high), interspersed with rambutan (Nephelium lappaceum L.; Sapindales: Sapindaceae) trees. The group of 20-30 wild "Criollo" avocado trees were growing between vestiges of coffee (*Coffea arabica* L.; Gentianales: Rubiaceae) and cocoa (*Theobroma cacao* L.; Malvales: Malvaceae) crops mixed with native vegetation, located within the ejido "El Aguinal" (N 14° 54' 21.7' W 92° 13' 43.4'; 200 m asl) in the municipality of Tuxtla Chico. On this site the avocado trees exceed 10 m in height. The management practices (e.g., pesticide applications, irrigation, pruning, fertilization, etc.) applied to the avocado trees are not commonly used in this region; therefore, no insecticides were sprayed in the study sites.

Dry Season

The attractiveness of the S. catenifer sex pheromone during the fruiting period (ca. 5-6 mo) was evaluated by placing 5 traps made from thin plastic sheets $(28 \times 20 \times 12 \text{ cm})$, similar to Pherocon® IC wing traps (Trécé, Adair, Oklahoma). Each trap was baited with a 11×5 mm gray rubber septum (West Pharmaceutical Services, Pennsylvania) impregnated with 0.1 mg of pheromone in 100 µL hexane. The pheromone was synthesized as previously described (Millar et al. 2008). Baited traps were hung individually on a tree branch 2 m above ground from 3 to 31 May 2011. The weather data of this month were obtained from weather stations close to "El Carmen" (24 \pm 10 °C; 74 \pm 51% RH; rainfall: 771 mm), "La Soledad" (26 \pm 7 °C; 87 ± 40% RH; rainfall: 404 mm) and "El Aguinal" (29 ± 11 °C; 73 ± 36% RH; rainfall: 234 mm). An unbaited trap, used as control, was placed in the same tree. The randomly selected trees were separated by a distance of 20-30 m and traps were checked weekly to collect captured moths. The bait was left unchanged at each season evaluated. At all sites, fallen fruit were collected and dissected in the laboratory to determine infestation levels. Larvae were obtained from fruit were placed individually into glass vials $(10 \times 1.7 \text{ cm})$ with 2 mL of a modified coffee borer (Hypothenemus hampei) (Ferrari) meridic diet (Villacorta et al., 1998), using soybean (Glycine max (L.) Merr.; Fabales: Fabaceae) instead of coffee powder, assuming that the nutritional needs must be similar between both species. Larvae were held inside the vials until adult moth emergence $(25 \pm 2 \text{ °C})$; 80% ± 5 RH).

Wet Season

From 30 Aug to 27 Sep 2011, during the nonfruiting period, 3 baited traps were placed on randomly selected avocado trees at the "Criollo" avocado orchard ("La Soledad") (26 \pm 8 °C; 94 \pm 34% RH; rainfall: 638 mm) and on wild "Criollo" avocado trees ("El Aguinal") (27 \pm 10 °C; 79 \pm 33% RH; rainfall: 506 mm). Each tree with a baited trap also had an unbaited trap as a control. Additionally, to analyze the effect to the avocado tree in the captures, 3 pheromone-baited traps were placed on other species of trees (*Tabebuia rosea* DC; Lamiales: Lamiaceae); *Guazuma ulmifolia* Lam., Malvales: Malvaceae, and *T. cacao*), 150 m away from the wild avocado trees at "El Aguinal". One baited trap and 1 unbaited trap (control) were placed in each non-avocado tree. Traps were checked weekly (Sep 2011), and moths were removed from the trap, preserved in vials containing alcohol (70%) and identified in the laboratory. Moth species were identified by comparing with specimens captured by Hoddle et al. (2011).

Data Analysis

Trap catch data was transformed with a square root transformation prior to a factorial analysis (ANOVA). The control was not included in the analysis, because no moths were captured in any control traps. Tukey's test was applied to dates with differences between treatments. Dates were analyzed with the program R-Core Team (2011).

RESULTS

Dry Season

This period coincided with the fruiting period, but no moths were trapped in the 'Hass' avocado orchard, whereas males of 2 moth species were captured at the other sites. While, only S. catenifer (n = 15) was caught in the 'Criollo' orchard, both S. catenifer (n = 7) and A. nictitans (n = 12)were captured at the wild tree site (Fig. 1). No significant interactions between date and species-locality variables (F = 0.42, df = 6, P = 0.08) were observed in the ANOVA. The captures of S. catenifer were 0.3 ± 0.1 and 0.7 ± 0.3 moth/trap/ wk (mean \pm SE) on wild trees and the orchard, respectively; whereas the capture of A. nictitans was 0.6 ± 0.2 moth/trap/wk at the orchard, but the number of moths captured by species in each locality was similar (F = 0.42, df = 2, P = 0.66) (Fig. 2). The number of moths captured decreased gradually with respect to time since deployment of the lure (F = 6.23, df = 3, P = 0.001). The highest moth capture rate occurred during the first week (mean: 0.9 moth/trap/wk) and the lowest capture was observed during the last 2 wk of observation (mean: 0.2 moth/trap/wk). In this same period, the range of infestation of S. catenifer was $0.18\mathchar`-0.5$ larvae/fruit at the wild avocado tree site and 0.13-0.25 larvae/fruit in the orchard (Fig. 3). Larvae of A. nictitans were not collected from infested fruits, only larvae of S. catenifer (Table 1).

Wet Season

Antaeotricha nictitans was the only species captured in the "Criollo" avocado orchard and



Fig. 1. Larva of *Stenoma catenifer* in an avocado fruit (A), trap baited with the sex attractant pheromone (B), adult male of *S. catenifer* (C) and adult male of *Antaeotricha nictitans* (D).

at the wild avocado site during this period (nonfruiting). ANOVA showed no interaction between "locality" and "lure age" variables (F = 0.13, df = 3, P = 0.92). The number of *A. nictitans* males captured was similar in both localities (F = 0.10, df =



Fig. 2. Males of *Antaeotricha nictitans* and *Stenoma catenifer* captured in traps baited with the sex attractant pheromone of *S. catenifer* on 'Criollo' avocado trees (cultivated and wild), during the dry season (fruiting period).

1, P = 0.75). The age of the lure did not show an effect on the number of captured moths (F = 0.10, df = 1, P = 0.75) (Fig. 4).

The captures obtained in other species of trees and avocado were analyzed separately, but no interaction was observed in the "tree species" and "lure age" variables (F = 1.98, df = 3, P = 0.16). The number of males captured was not affected by trees species (F = 0.49, df = 1, P = 0.49), or lure age (F = 1.7, df = 3, P = 0.21) (Fig. 5).

DISCUSSION

We confirm the presence of *S. catenifer* in this region of Mexico, as previously reported (Hoddle et al. 2011). However, this is the first report of this pest being detected under wild conditions in the Mesoamerican zone of origin of avocado (Williams 1977). This supports the idea of the geographic



Fig. 3. Infestation levels of avocado fruits with *Stenoma catenifer* larvae on "Criollo" avocado trees (cultivated and wild).

origin of the pest (Busck 1919), which could have serious implications for the recent interest in growing avocado commercially in this part of Mexico. Since 2009, 600,000 'Hass' avocado trees have been planted in Chiapas, near to the border with Guatemala (Secretaría del Campo, unpublished data). The results indicate that so far this pest has not invaded these 'Hass' avocado plantations, perhaps because the plants are not yet producing fruit.

Also, this work confirmed that the S. catenifer pheromone attracted male A. nictitans under field conditions as reported by Hoddle et al. (2011). This suggests that these 2 Elachistidae species share one or more sex pheromone components. Similar interspecific attraction of a sex pheromone in Lepidoptera has been found, for example, between the Noctuidae Trichoplusia ni and Pseudoplusia includens (Landolt & Heath 1987) and the Pyralidae Pyralis farinalis and Amyelois transitella (Landolt & Curtis 1982). The number of captured moths per species was not different in each locality; however, the pheromone allowed us to detect qualitative differences (per site and with the passage of time) between both captured species. Although the seasonalities of both captured species were unknown until now, this study demonstrated that this pheromone could be used to obtain important information about the biology and ecology of these species. Some studies, such as the population dynamics of S. catenifer (Nava et al. 2005), carried out by dissecting infested fruit, could be complemented with the monitoring of adults using this pheromone.

Stenoma catenifer was captured during the dry season (May) at both the wild and cultivated avocado sites, but never during the rainy season (Sep). The capture of S. catenifer adults in the dry season coincides with the presence of their larvae in the infested fruits. In previous studies, various species of Lepidoptera were recorded infesting avocado fruit in plantations of Guatemala (Hoddle and Hoddle 2008b). In contrast, we found only S. catenifer larvae infesting fruit. Our results suggest that the seasonal attraction of males to this pheromone does not seem to be directly determined by climate, but is being conditioned to a certain extent by food availability. Stenoma catenifer prefers avocado fruits as its oviposition substrate, but it is also capable of infesting avocado branches and stems (Hoddle 2009). However, not all tropical insect species occur throughout the year as active adults (Wolda 1988). Therefore, it is possible that S. catenifer adults were not detected during the wet season because adults may not occur during this non-fruiting period. The efficiency of the Stenoma lures has been evaluated previously (Hoddle et al. 2009, 2011); however, low trap capture efficiency seems to be a limiting problem in some instances (Weinzierl et al. 1995). In our case, the complete absence of moths in the

TABLE 1. AVOCADO FRUITS COLLECTED AND S. CATENIFER (LARVAE AND ADULTS) OBTAINED DURING THE DRY SEASON FROM TWO SITES IN SOUTH OF MEXICO.

Sites	Collected	Infested fruits	Obtained	Parasitized larvae	Obtained adults
	fruits	(%)	larvae	(%)	(%)
"El Aguinal" "La Soledad"	33 66	$\frac{10(15.2)}{10(30.3)}$	$\begin{array}{c} 0.38\\ 0.74\end{array}$	3 (30) 0 (0)	7 (30) 10 (100)

control traps (traps without pheromone) suggests that this bait had a decisive effect on the attraction of both species. Nevertheless, our results showed a reduction in number of captures as trap exposure time increased, suggesting a loss of attractant activity of the pheromone or a decrease in the moth population density. In a previous study, the attractiveness of this pheromone did not change during a mo of observation (Hoddle et al. 2009). Consequently, more detailed studies of pheromone release devices and/or stabilizers may be warranted, in order to provide lures with extended field lifetimes.

The variation in the abundance of insects in tropical regions is well known, but not all species respond in the same manner to changes in the climate and availability of food (Wolda 1988). In the case of A. nictitans, males were captured during both seasons under wild conditions, while at the "Criollo" avocado plantation they were caught only during the rainy season. These results indicate that A. nictitans adults were always present in an undisturbed environment, independent of season. Most tropical species are relatively intolerant of conditions prevailing in cleared areas, because of microclimatic changes and reduced resource supply (Klein 1987). Perhaps such changes in the "Criollo" avocado orchard did not allow the capture of A. nictitans adults during the dry season. Although the size and degree of isolation of habitat remnants are important, the frequency and intensity of human disturbances, in addition



Fig. 4. Antaeotricha nictitans males captured in traps baited with the sex pheromone of Stenoma catenifer on "Criollo" avocado trees (cultivated and wild), during the rainy season (non-fruiting period).



Fig. 5. Antaeotricha nictitans males captured in traps baited with the sex pheromone of Stenoma catenifer placed on wild trees (avocado and non avocado) during the rainy season.

to the type of surrounding vegetation and landscape arrangements, can be crucial in the persistence of species (Weins et al. 1993), which without doubt favored the abundance of *A. nictitans* adults during the rainy season. Additionally, as with the majority of tropical insects, the most difficult time for *A. nictitans* adults could be the dry season (Janzen 1991). These species reach their adult stage during the rainy season, thanks to a larval or pupal diapause during the dry season (Janzen 1987).

Although A. nictitans seems not to attack the avocado fruits, it could, perhaps, be a boring pest of the branches of avocado. However, our results suggest that probably the adult males of A. nictitans come from the vegetation surrounding avocado trees, because: i) larvae were not found infesting avocado fruit, ii) male adults were always captured under undisturbed conditions, and iii) adult males were not captured during the dry season (the most adverse season) within the crop. These observations lead us to suspect that adults of A. nictitans are visitors of the crop, although the host for this species remains unknown. Finally, we conclude that this pheromone has the potential to be a useful tool for detecting this pest in avocado crops of the region, although its use in control programs will require additional training of personal responsible for trapping and specimen identification.

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