SEASONAL AND NOCTURNAL FLIGHT ACTIVITY OF SPODOPTERA FRUGIPERDA MALES (LEPIDOPTERA: NOCTUIDAE) MONITORED BY PHEROMONE TRAPS IN THE COAST OF CHIAPAS, MEXICO

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SEASONAL AND NOCTURNAL FLIGHT ACTIVITY OF *SPODOPTERA FRUGIPERDA* MALES (LEPIDOPTERA: NOCTUIDAE) MONITORED BY PHEROMONE TRAPS IN THE COAST OF CHIAPAS, MEXICO

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ABSTRACT

We determined seasonal and nocturnal flight activity of *Spodoptera frugiperda* (J. E. Smith) males with traps baited with pheromone in the coast of Chiapas, Mexico. A total of 3015, 3065, and 838 males were captured in 2000, 2001, and 2002, respectively. Pheromone trap catches decreased approximately 72% during 2002 with respect to 2000 and 2001. One of five experimental sites caught 90% of the total captured. The pattern of trap captures was quite variable among years and sites. In general, the flight activity of *S. frugiperda* males was seasonal, with two distinctive peaks in trap captures during the year. Males were caught during all hours of scotophase, however, most males were captured during the first 7 h. Highest peak capture was between 1900-2000 h. Trap captures were positively correlated with wind speed and temperature, and negatively correlated with relative humidity. Significantly more males were captured at wind speeds of 100-200 and >200 m/min than at wind speeds of 0-100 m/min.

Key Words: *Spodoptera frugiperda*, pheromones, monitoring, seasonal activity, nocturnal activity, Mexico.

RESUMEN

La actividad de vuelo estacional así como la actividad nocturna de machos de *Spodoptera frugiperda* (J. E. Smith) fue determinada usando trampas cebadas con feromona en la costa de Chiapas, México. Un total de 3015, 3065 y 838 machos fueron capturados en 2000, 2001 y 2002, respectivamente. La captura de las trampas cebadas con feromona, disminuyó aproximadamente en un 72% en 2002 con respecto al 2000 y 2001. El perfil de captura de machos de *S. frugiperda* fue muy similar en 2000 y 2001, pero diferente al del 2002. En los dos primeros años se obtuvieron grandes capturas de machos de *S. frugiperda* en los meses de enero a marzo. Por el contrario en 2002, las mayores capturas se obtuvieron en agosto. Del total de machos capturados, más del 90% fueron capturados en un sitio experimental y el 10% restante en las otras localidades estudiadas. En cuanto al estudio de la actividad nocturna de los machos de *S. frugiperda* con trampas cebadas con feromona, se encontró que la captura se inició desde las primeras horas y se mantuvo durante toda la noche. Sin embargo, la mayoría de los machos fueron capturados durante las primeras siete horas de la noche, alcanzando el mayor pico de captura entre las 1900-2000 h. Las capturas obtenidas con las trampas correlacionan positivamente con la velocidad del viento y la temperatura, y de manera negativa con la humedad relativa. Se capturaron de manera significativa más machos cuando la velocidad del viento fue de 100-200 y mayor de 200 m/min, que cuando fue de 0-100 m/min.

Translation provided by the authors.

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) is indigenous to the tropical regions of the western hemisphere from Argentina to the United States of America. This species is considered a generalist feeder, feeding on a very wide host range of plants in several families, with preference for grasses. In Mexico, FAW is one of the most important pests of corn and sorghum, although occasionally it attacks other crops. It frequently is controlled through the use of insecticides. The misuse of insecticides has led to resistance of *S. frugiperda* to several insecticides in Mexico (Pacheco-Covarrubias 1993) and to possible harmful effects on human health and the environment (Tinoco & Halperin 1998). Alternatives for managing this pest are currently being explored in Mexico, including the use of agents of biological control, cultural techniques, host plant resistance and pheromones (Malo et al. 2001; Cisneros et al. 2002; Mendez et al. 2002; Farias-Rivera et al. 2003; Molina-Ochoa et al. 2003).

Pheromones can be used for direct control of some insect pests (mass trapping, kill and lure, and mating disruption) and for monitoring pest populations. Pheromone-monitoring traps can be used for detection of a particular species, timing of control measures, and economic risk assessment of that pest (Wall 1990). In the case of *S. frugiperda*, pheromone has been used mainly to monitor male activity, in determining migration, seasonal dynamics, and spatial distribution (Tingle & Mitchell 1979; Waddill et al. 1982; Starrat & McLeod 1982; Pair et al. 1986; Adams et al. 1989; Mitchell et al. 1989). The possibility of using pheromone as a direct way of control has been less explored (Mitchell et al. 1974a).

FAW is a key pest of corn in Chiapas, Mexico, but information on moth seasonal dynamics and flight patterns is lacking for this region. The objective of this study was to provide information on seasonal and nocturnal flight activity of FAW males in the coast of Chiapas with traps baited with sex pheromone. The information obtained could be integrated to the control measures to manage *S. frugiperda* infestations in an effective manner.

Materials and Methods

Seasonal Flight Activity

We selected five sites in three municipalities at the coast of Chiapas, Mexico (Fig. 1). This region experiences a humid temperate climate with heavy rain in the summer, with average annual rainfall of 2,063 mm, with a rainy season normally occurring from late May through November. The average annual temperature is 26°C, and April and May are the hottest months. Most of the land is flat, but there are rolling hills in the Northeast region. The most common soil types are luvisol, nitosol andosol, and planosol. A great diversity of plants are cultivated, including annual (e.g., corn, sorghum and soybean) and perennial crops (e.g., mango, coffee, and cacao). Many hectares are dedicated to cattle ranching, with less space devoted to pigs and poultry. Two of the sites selected were located in the Tapachula municipality. In the first site, "Los Toros" (14°48'N, 92°19'W, 40 masl), 45 ha of soybean are cultivated once a year (June to October). Mango orchards and native trees surround this area. In this site, traps were placed 15 m away from a living fence of *Jatropha curcas* L.

The second site is known as "El Manzano" (14°44'N, 92°19'W, 20 masl), where about 700 ha are devoted to cultivation of two crops annually. Sorghum or corn is cultivated from January to May, and is watered by a sprinkler irrigation system. Soybean is cultivated during the rainy season from July to October. In this site, traps were placed 200 m away from a cashew orchard. Two additional sites were selected in the municipality of Suchiate; the first known as "20 de Noviembre" (14°42'N, 92°16'W, 20 masl), where 108 ha are dedicated to cultivate star grass (*Cynodon nlemuensis* Vanderyst) for feeding cattle. Mango orchards and native trees surround the area. In this site, traps were placed 200 m away from a patch of native trees. In the second site called "Ciudad Hidalgo" (14°40'N, 92°10'W, 25 masl), 13 ha are devoted to cultivation of corn once a year from June to September. Banana plantations, mango orchards and native trees surround the area. In this site, traps were placed 20 m away from a patch of native trees. The fifth site known as "Chincuyo" (14°51'N, 92°11'W, 155 masl) was located at the municipality of Tuxtla Chico, where 2 ha of corn are cultivated during the rainy season from June to October. Cacao and lemon orchards surround the site. Traps were placed 20 m away from a lemon orchard.

At each site, two Scentry *Heliothis* traps were placed 1.5 m above the ground on wooden stakes, spaced more than 30 m apart. Each trap was baited with a *S. frugiperda* pheromone bubble cup lure (Chemtica, Costa Rica) that was replaced monthly. Moths were collected every 10 d, counted, and numbers recorded by trap and locality. Trapping was conducted from January 2000 to December 2002, resulting in a total of 103 observation dates.

Nocturnal Flight Activity

This experiment was conducted at El Manzano locality in Tapachula. The experimental field was planted with sorghum ('V-M') variety sown at a density of 50,000 plants/ha with row spacing of 0.75 m. Four Scentry *Heliothis* traps were placed at intervals of 100 m in a straight line inside the field, starting with the first trap 100 m from the crop edge. Traps baited with a *S. frugiperda* pheromone formulated as a bubble cup (Chemtica, Costa Rica) were hung approximately 1.5 m above the ground on wooden stakes. When the experiment began, sorghum plants were 25 cm high. Traps were emptied each h, beginning at 1800 h (30 min before sunset) until 6000 h (10 min before dawn). Males caught in each h were killed with ethyl acetate and counted. Before each observational night, traps were cleaned and rotated along the line to remove possible trap bias on male capture. In addition, temperature, relative humidity, wind direction, and wind speed each 5 min were recorded 2 m above ground level at the edge of the field. The experiment was conducted during 5 nights, from 10-14 February, 2003.

Statistical Analysis

Analysis of variance (ANOVA) was used to determine if the number of males caught varied through the night. Data were transformed by ln (X + 1) before ANOVA, to correct for heterogeneity of variances. A possible correlation between the number of males trapped and the meteorological parameters recorded was examined by Spearman rank correlation analysis. Data from all traps were used for the correlation analysis because preliminary analysis showed that trap position did not influence the numbers of males captured.

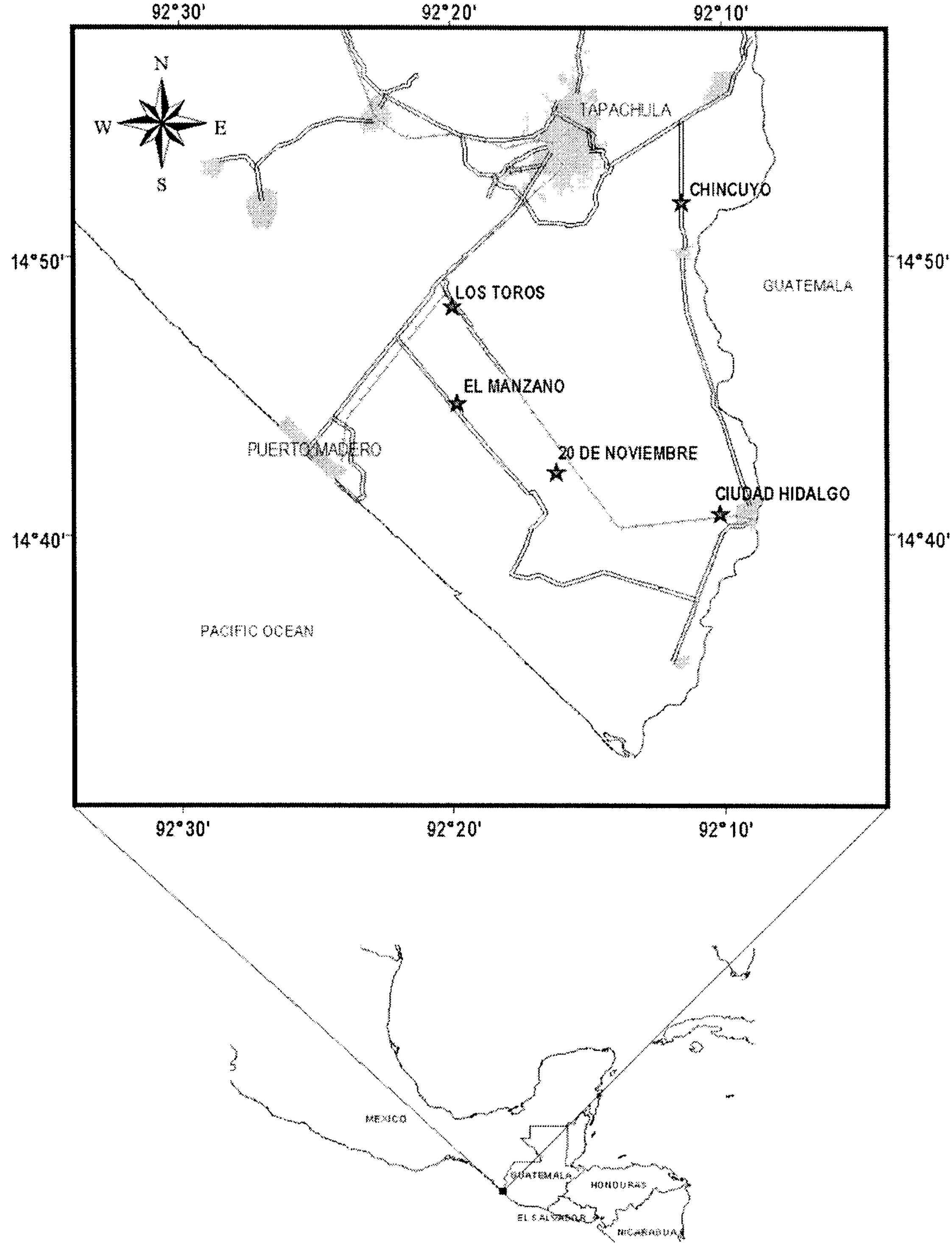

Fig. 1. Map showing where pheromone traps were placed in Soconusco region, Chiapas, Mexico during 2000-2002. The sites sampled are marked with black stars.

Also, wind speed was categorized as light (0-100 m/min), moderate (100-200 m/min), or strong (>200 m/min), and an ANOVA performed among the traps captures across wind-speed categories. When statistical significance was found after ANOVA, treatment means were separated by the Tukey test procedure. The level of probability considered significant in all analysis was $P \leq 0.05$.

Results

Seasonal Flight Activity

A total of 6770 *S. frugiperda* males was captured during the three years of trapping. A total of 3015, 3065, and 838 males was captured in 2000, 2001, and 2002, respectively. Pheromone trap catches decreased approximately 72% during 2002 compared to 2000 and 2001. The El Manzano site caught 93.4% of all males captured among the sites. The pattern of trap captures was quite variable among years and sites (Fig. 2). For example, the pattern of trap captures in El Manzano was quite similar during 2000 and 2001, but slightly different in 2002. In the first two years, the flight activity of *S. frugiperda* males was seasonal, with two distinctive peaks in trap catches. The first peak occurred from January to March during the dry season, and the second peak between June and September, during the rainy season. During 2002, there were also two peaks, the first between January and February, and the second one occurred in August. In the other sites the flight activity of *S. frugiperda* was also bimodal, the first and higher peak occurred between June and July, whereas a smaller peak was observed between September and November at the end of the rainy season. No moths were caught from January to April during the three years in the experimental sites Chincuyo, 20 de Noviembre and Los Toros, except that a small number of males was caught at Los Toros in 2001 (Fig. 2).

Nocturnal Flight Activity

The trap position within the field did not affect the number of males captured during the experiment ($F = 0.7$; $df = 3, 16$; $P = 0.57$). The nocturnal activity of *S. frugiperda* males began at sunset and they were active throughout the night, although the number of males trapped varied significantly through time ($F = 4.5$; $df = 11, 228$; $P < 0.0001$). Most males were captured during the first 7 h, with the highest catches between 1900 and 2000 h (Fig. 3). Trap captures were positively correlated with wind speed ($r = 0.29, P = 0.03$) and temperature ($r = 0.32, P = 0.016$), and negatively correlated with relative humidity ($r = -0.32, P = 0.016$). More males were captured at wind speeds of 100-200 and >200 m/min than at wind speed of 0-100 m/min ($F = 4.9$; $df = 2, 50$; $P = 0.01$) (Fig. 4).

Discussion

Our results show great variation in the number of *S. frugiperda* males caught among the different experimental sites, with the "El Manzano" site capturing most of the insects. Capture of adults at this site was bimodal, the greatest number captured from January to March, in the dry season, with a second smaller peak between June to September, during the rainy season. In general, our results from this site are in agreement with those reported by Raulston et al. (1986), who investigated the population trends of *S. frugiperda* along the Mexican Gulf Coast, the Isthmus of Tehuantepec, and the Yucatan Peninsula with Harstack pheromone traps. They found that low numbers of males were caught during the mid-portions of the year, while peak captures occurred either early or late in the year. In contrast, the highest captures occurred during the rainy season and a few males were captured in the dry season at the other trap sites. These results agree with those of Mitchell et al. (1991), who reported that in the tropics, *S. frugiperda* populations have a tendency to vary with seasonal changes in rainfall, with the lowest populations recorded during the dry seasons. In French Guiana, the highest populations of adults and larvae of *S. frugiperda* occur during the rainy season and the lowest in the dry seasons (Silvain & Hing 1985). Our study was conducted in a relatively small area and factors such as temperature and rainfall are expected to be quite similar and therefore these hardly could explain the difference in traps captures among experimental sites. Gutierrez-Martinez et al. (1989) reported that temperature and rainfall did not affect the captures of *S. frugiperda* males in the central area of Chiapas State, Mexico. On the contrary, the wind speed and direction changes from place to place, and this variation could explain why traps placed at El Manzano captured more males than other sites. Also, "El Manzano" is not surrounded by native or cultivated trees (e.g., mangoes) as was the case with the other experimental sites, which may constitute a barrier for both insects and pheromone dispersion. It has been documented that the distinct plume of pheromone is constructed from the pheromone source and a large proportion of males entering it can reach the source when the wind is strong (Lewis & Macaulay 1976). Mitchell et al. (1991) reported that favorable wind currents contributed to the distribution of *S. frugiperda* into and from different areas in the USA. However, the most important factor affecting trap captures seems to be the availability of host plants. For example, average host area in El Manzano was 6.8, 16.4, 56.7, and 368.5 times higher than in 20 de Noviembre, Los Toros, Ciudad Hidalgo and Chincuyo, respectively. Also, at El Manzano, a greater number of *S. frugiperda* males/trap/day was

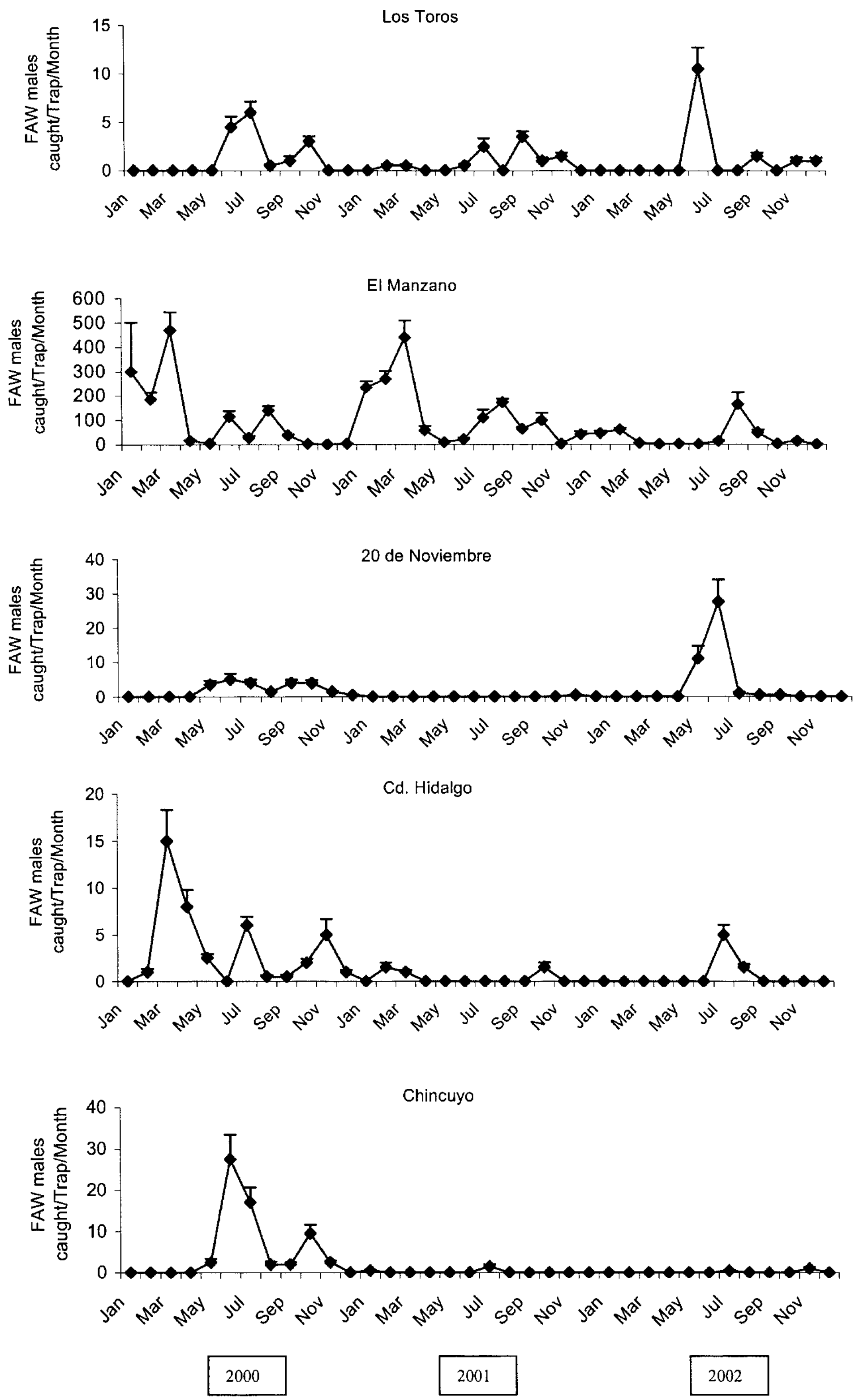

Fig. 2. Mean number of *S. frugiperda* males caught with pheromone traps at five sites in Soconusco region, Chiapas, Mexico during 2000-2002. Lines extending from each dot are standard error of the mean.

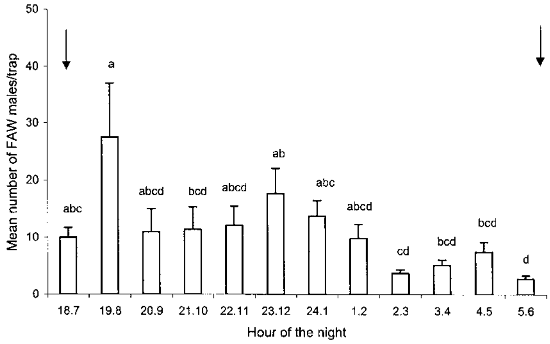

Fig. 3. Nocturnal flight of *S. frugiperda* males (mean ± SE) caught with pheromone traps during five successive nights from 10-14 February, 2003. Arrows indicate sunset and sunrise. Values (mean ± SE) followed by the same letter indicate no significant differences at the 5% level according to the Tukey test.

caught when crops (sorghum or corn and soybean) were present than when crops were absent (Mean ± SE = 5.8 ± 0.7 and 3.4 ± 0.7, respectively) ($t = 2.1$, $df = 93$, $P = 0.04$). Gutierrez-Martinez et al. (1989) showed that the first *S. frugiperda* males are captured right after plant emergence, with the highest frequency from the 10th through the 41st day of emergence, when the plant is more susceptible. Pair et al. (1986) reported that the availability and amounts of susceptible stages of corn planted in more northerly areas may be the most important factors determining the magnitude of *S. frugiperda* populations each year throughout the southeastern states of the USA. In other moth species, it also has been shown that host availability influences trap captures (Slosser et al. 1987; Parajulee et al. 1998).

We found that *S. frugiperda* populations were lower in 2002 than in 2000 and 2001 despite the fact that cropping patterns and total crop area did not vary during the three-year study. Thus, host availability cannot explain the decrease of FAW populations in 2002. One possible explanation is that climatic factors affected the populations. Pair et al. (1986) reported that *S. frugiperda* populations were lower in 1984 than in 1983 or 1985 in the southeastern states of USA. The authors mentioned that one possible cause of the diminution of populations in 1984 was the colder temperature, 0°C or lower recorded in winter 1983 and spring 1984 in the study area. It is known that 0°C kill *S. frugiperda* life stages and their host plants (Luginbill 1928). In our case, the minimal temperatures recorded in winter were about 19°C. Thus, low temperature does not seem to explain the decrease of populations in 2002. Rainfall is another possible factor to explain the lower capture rates of *S. frugiperda* males in 2002. Van Huis (1981) reported that heavy and light rain kill significant numbers of early instars of FAW. Data from a meteorological station located 10 km away from El Manzano show that it rained in December 2001, but not in December 1999 and 2000. Thus, it is possible that this rain killed *S. frugiperda* larvae, which reduced adult populations.

We found that *S. frugiperda* males were caught throughout the night but trap captures among night intervals was variable. Most males were captured during the first 7 h, reaching the highest capture peak between 1900 and 2000 h. That males responded to pheromone traps during the whole night could be due to the fact that we used synthetic lures which continuously emit pheromone and response could be independent from female calling periodicity. Mitchell et al. (1974b), who used *S. frugiperda* virgin females as lures, found that males responded to traps from 0.5 h before sunset to 1.5 h before sunrise, which is in agreement with our results.

Raina & Menn (1987) indicated that synchronous timing of calling behavior of females and flight activity of males in Lepidoptera could provide a high probability of mate finding with a minimum expense of energy. We do not have information about the diel periodicity of calling behavior of *S. frugiperda* females in the field, but under laboratory conditions, 2-d-old virgin females started to call 90 min after lights were turned off and individuals called throughout the night. Females stopped calling as soon as lights were turned on. Older females began to call 15 min after lights were turned off and calling peaked 3 h after lights were off (Reyes-Galvez 1999). In another study, mating pairs of *S. frugiperda* were observed throughout the night, although the percentage of moths in copulation peaked 3-4 h into the dark cycle (Simmons & Marti 1992). Temporal differences between peak calling, mating, and peak male flight may be attributed to differences in temperatures and photoperiod regimes. In other moth species, the flight

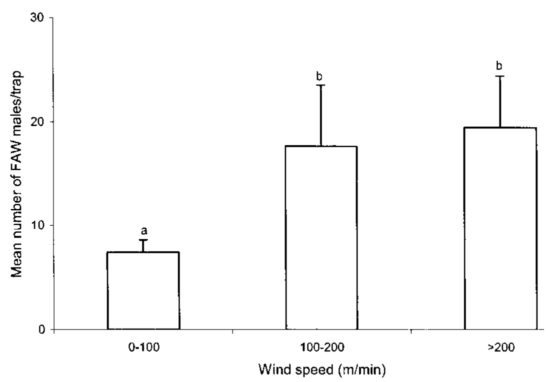

Fig. 4. Effect of wind speed on *S. frugiperda* capture with pheromone traps. Values (mean ± SE) followed by the same letter indicate no significant differences at the 5% level according to the Tukey test.

time of males is well synchronized with female calling (Cardé 1974; Sasaki & Riddiford 1984; Cibrian-Tovar & Mitchell 1991). However, in some cases, the calling behavior of females and the activity cycle of males seems not to be well coordinated because the peak of male flight does not coincide with the peak of female calling (Sanders 1971; Cardé 1974). For instance, females of *Choristoneura fumiferana* (Clemens) started calling 4.5 h before sunset and the peak of females calling was reached 2.5 h later. On the other hand, males were caught at all times during the 24 h period and the peak catch occurred 1.5 h after sunset. These results suggest that factors other than the release of pheromone have strong influence on the activity of *C. fumiferana* males (Sanders 1971).

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