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PHEROMONE TRAP FOR MONITORING *COPITARSIA DECOLORA* (LEPIDOPTERA: NOCTUIDAE) ACTIVITY IN CRUCIFEROUS CROPS IN MEXICO

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Abstract

Copitarsia decolora (Guenée) is an important pest of several crops such in Mexico, Central and South America. In addition, this species is a regulatory concern in the USA. In this work, we investigated the influence of trap design, trap height, and trap color on pheromone trap catches of *C. decolora* males in cruciferous crops. Additionally, we investigated the seasonal dynamics of *C. decolara* for 3 yr. The water-trap captured a significantly higher number of males compared to the jug trap and the Scentry® *Heliothis* trap. There were no significant differences between in the number of males captured by traps positioned at 0.5, 1, and 1.5 m above ground level. There was also no an interaction between trap design and trap height. Green water-traps captured more males than red water-traps, however, the catches of red water-traps were intermediate and not significantly different from those captured by yellow, blue, and brown water-traps. A total of 6,978 *C. decolora* males were captured during the 3 yr of trapping. The overall distribution of trap captures over the season was unimodal, with a distinctive peak in trap catches occurring between Mar and Apr.

Key Words: *Copitarsia decolora*, monitoring, sex pheromone

Resumen

Copitarsia decolora (Guenée) es una plaga importante de diversos cultivos en México, Centro y Sudamérica, y esta especie está cuarentenada en los Estados Unidos de América. En este trabajo se estudiaron la influencia del diseño de trampa, la altura a la que se ubica la trampa, y el color de la trampa en la captura de machos por trampas cebadas con feromona en cultivos de cruciferas. Adicionalmente, nosotros investigamos la fluctuación poblacional de *C. decolora* por 3 años usando trampas con feromona. La trampa de agua capturó significativamente un número alto de machos comparado con la trampa de jugo de plástico y la trampa Scentry *Heliothis*. No hubo diferencia significativa en el número de machos capturados por trampas colocadas a 0.5, 1, 1.5 m arriba del nivel del suelo. Además, no hubo interacción entre el diseño y la altura de la trampa. La trampa de agua de color verde capturó más machos que la trampa de color rojo. El número de machos capturados por las trampas de color amarillo, azul y café no fue significativamente diferente del número capturado por las trampas verdes y rojas. En total se capturaron 6978 machos en los 3 años de muestreo. En general, la distribución de las capturas a través del año fue unimodal con un distintivo pico ocurriendo entre marzo y abril.

Palabras Clave: *Copitarsia decolora*, monitoreo, feromona sexual

Translation provided by authors

The moth, *Copitarsia decolora* (Guenée), is one of the most important pests of several crops such as alfalfa (*Medicago sativa* L.; Fabales: Fabaceae), pea (*Pisum sativum* L.; Fabales: Fabaceae), potato (*Solanum tuberosum* L.; Solanales: Solanaceae), carrot (*Daucus carota* L.; Apiales: Apiaceae), cabbage (*Brassica oleracea* L.; Brassicales: Brassicaceae), and common bean (*Phaseolus vulgaris* L.; Fabales: Fabaceae), in Central and South America (Simmons & Scheffer 2004). In Mexico, this insect is distributed in Chiapas, Veracruz, Puebla, State of Mexico, Morelos, Guanajuato, and San Luis Potosi, where it is commonly associated with cole crops (Brassica spp.;

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Brassicales: Brassicaceae), coriander (*Coriandrum sativum* L.; Apiales: Apiaceae); Mexican tea (*Chenopodium ambriosioides* L; Caryophyllales: Chenopodiaceae), and pitseed goosefoot (*Chenopodium berlandieri* ssp. *nuttalliae* Wilson & Heiser; Caryophyllales: Chenopodiaceae) (Torres-Nohra & Rangel-Machain 2003, Fernández-Cevada & Vazquez-Ortiz 2003, Flores et al. 2004, Suárez Vargas et al. 2006). The damage of this insect reduces yields and marketability of the crops attacked (Venette & Gould 2006). For example, in cabbage a single larva is enough to produce significant qualitative and quantitative injury (Monge-Villalobos et al. 1984). In addition, this species and other members of the genus *Copitarsia* are of regulatory concern in the United States (Gould et al. 2005). These insects are high-risk pests for agriculture in the USA (Gould et al. 2005; Venette & Gould 2006).

The control of *C. decolora* relies almost exclusively on synthetic insecticides (Larrain & Araya 1994; Díaz-Gómez et al. 2003; Pérez et al. 2009), which may cause undesirable effects on human health or in the environment, if not used appropriately. Therefore other pest management strategies need to be evaluated. Pheromone traps have become an important tool for monitoring pest populations in a range of crops (Herman et al. 2005). Recently, the sex pheromone of *C. decolora* was identified as a blend of (*Z*)-9-tetradecenyl acetate (Z9-14: Ac) and (*Z*)-9-tetradecenol (Z9-14: OH) (Rojas et al. 2006). Captures is traps baited with a blend of Z9-14: Ac and Z9-14: OH at 1:1, 4:1, 10:1, and 100:1 ratios were not significantly different from the catches in traps baited with virgin females. In contrast, few males were captured in traps baited with a blend of Z9-14: Ac and Z9-14: OH at 1:4, 1:10, and 1:100 ratios (Rojas et al. 2006). However, several factors need to be evaluated before the pheromone can be used effectively for monitoring *C. decolora*. The relative efficiency of pheromone traps depends on factors such as a proper trap type, optimal trap height, and trap placement (Wall 1989).

In this study, we evaluated the influence of trap design, trap height, and trap color on pheromone trap captures of *C. decolora.* In addition, we investigated the seasonal dynamics of this moth for 3 yr. The information obtained in this study may be useful for monitoring this pest in one of the most important areas of commercial vegetable production in Mexico.

Materials and Methods

Study Area

The experiments were performed in the ranchos "La Barda" (22°10'N, 100°53'W, 1844 m asl), "Chicosein" (22°12'N, 100°54'W, 1844 m asl), both located in municipality of Soledad de Graciano Sánchez, and "San Francisco" (22°16'N 101°07'W, 2020 masl) located in municipality of Mezquitic de Carmona, San Luis Potosí, Mexico. The rancho "San Francisco" is located approximately 20 km from the ranchos "La Barda" and "Chicosein"; the distance between these last ranchos is about 5 km. Cauliflower, cabbage, and broccoli are grown year-round in "La Barda", "Chicosein, and "San Francisco", respectively. Typically, plants are sown in 1-2 ha fields at regular intervals of 3-4 wk to assure a constant supply of these food crops; so as soon as an area has been harvested, it is immediately prepared for sowing another crop. Other ranchos in the region also cultivate cruciferous crops under the same strategy. This region experiences a semi-arid climate with average annual rainfall of 362 mm, with a rainy season normally occurring from Apr to Sep. The average annual temperature is 17.1 °C, with May as the hottest mo (40 °C) and Jan as the coldest (8.5 °C).

Influence of Trap Type and Trap Height on Captures of *Copitarsa decolora* Males

In the first experiment, the influence of trap design and trap height on pheromone trap catch of males were evaluated in 2 different trials at the rancho, "La Barda". The first trial was performed from 17 Oct to 17 Dec 2008, and the second trial from 23 Jan to 23 Mar 2009. Three trap designs and 3 trap heights were evaluated in a 3 × 3 factorial experiment. The traps chosen have been used previously for monitoring other noctuids in Mexico (Tafoya et al. 1999; Malo et al. 2001; Malo & Rojas unpublished data). The treatments were arranged in a fully randomized block design with 4 replicates for each treatment. The pheromone lures tested were obtained from Pherocomps (Mexico City), and consisted of red rubber septa loaded with 1 mg of a 1: 1 blend of Z9-14: Ac and Z9-14: OH (Rojas et al. 2006). The purity of pheromonal components was 95% according to the supplier. Traps were spaced 30 m between blocks and 30 m between traps. All lures were changed monthly. The first trap evaluated was a water-trap type (Fig. 1) that consisted of two blue plastic containers, one container (14 cm high × 40 cm diam) was filled with soapy water for capturing male moths attracted to the lure, and the second (25 cm high × 20 cm diam) container had two lateral openings (7 × 10 cm) to allow the emission of the pheromone plume. The second container was inverted and placed into the first container. The pheromone lure was placed in the second container. The second type was a jug trap (Fig. 1) and consisted of a gallon (3.8 L) plastic milk container with 3 windows on the sides to allow pheromone dispersion and that males enter the trap. A 6 cm space between the windows and the bottom of the container is used as a reservoir that is filled with

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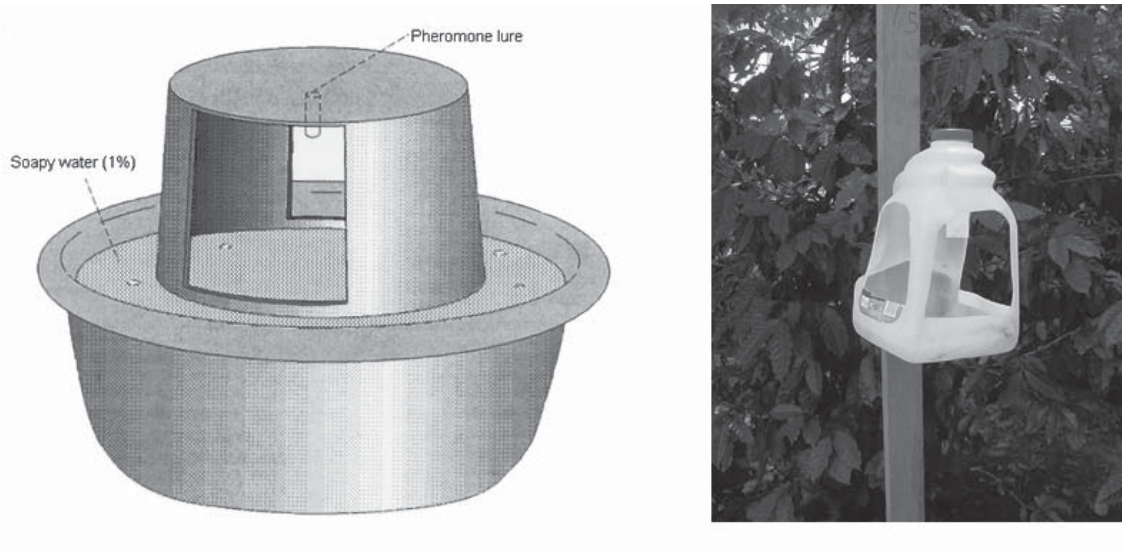


Fig. 1. Water trap and jug trap used to capture *Copitarsa decolora* males in in cruciferous crops in vegetable fields near San Luis Potosí, Mexico. Water-traps were placed on wooden platforms (30 × 30 cm), while the jug trap and the Scentry® *Heliothis* trap (not shown) were hung on wooden stakes. The soapy water (2%) of the jug and water traps was changed every 8 d. Traps were spaced 30 m apart.

soapy water. A paper clip, placed inside the jug cap, held the pheromone lure in place. The water of the jug and water traps was changed every 8 d. The third design evaluated was a Scentry® *Heliothis* trap, a white double cone collapsible plastic net (Ecogen Inc. Billings, Montana, USA). The traps were placed at heights of 0.5, 1, and 1.5 m above the ground, approximately 0.3, 0.8, and 1.3 m, respectively, over the plant canopy. The water-traps were placed on wooden platforms (30 × 30 cm), while the other two designs were hung on wooden stakes. Males captured in traps were recorded every 3 d. To minimize position effects, traps were rotated each time they were inspected. Previous observations have noted zero or few catches for unbaited control traps in comparison to traps baited with pheromone (Rojas et al. 2006). Consequently, unbaited control traps were not included in any of the experiments. The field trials were conducted in 5 ha-cauliflower fields with 37, 000 plants per hectare.

Influence of Trap Color on the Capture of *Copitarsa decolora* Males

In this experiment, we evaluated the effect of trap color, using water traps baited with sex pheromone, on the capture of *C. decolora*. This type of trap was chosen because it was the most effective for capturing *C. decolora* males in the previous experiment. The experiment was performed from 11 April to 13 May 2011 at the Rancho "La Barda". This experiment was conducted in 5 ha-cauliflower fields with 37, 000 plants per hectare. We used yellow, blue, green, brown and red traps. The spectral reflectance curves of the different colors were measured using a spectrometer (USB4000-VIS-NIR, Ocean Optics, Dunedin, Florida) with an optical resolution of about 1.5 nm (full width at half maximum), a tungsten-halogen light source (LS-1, Ocean Optics, Dunedin, Florida) and a reflection probe (R200-7-VIS-NIR, Ocean Optics, Dunedin, Florida). The reflectance curves for colors used are shown in Fig. 2. The treatments were arranged in a fully randomized block design with 4 replicates for each treatment. The pheromone lures used were obtained from Pherocomps (Mexico City) and formulated on rubber septa in a ratio of 1:1 of Z9-14: Ac and Z9-14: OH (Rojas et al. 2006). Traps were spaced 30 m between blocks

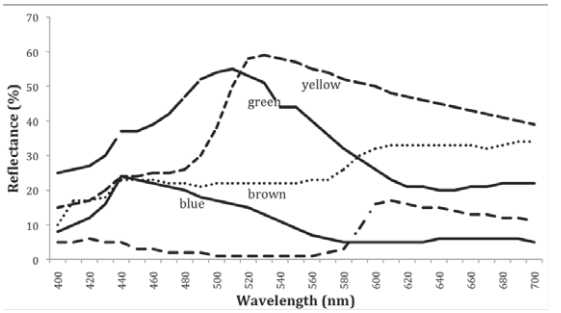


Fig. 2. Spectral reflectance curves of yellow, blue, green, brown, and red water traps used in the experiment on the effect of trap color on the capture of *Copitarsia decolora* males.

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and 30 m between traps. All lures were changed monthly. Males captured in traps were recorded every 3 d. To minimize position effects, traps were rotated each time they were inspected.

Seasonal Flight Activity of *Copitarsa decolora*

We selected three sites (La Barda, Chicosein, and San Francisco) for monitoring the seasonal activity of *C. decolora*. At each site, two water traps were placed 1 m above the ground, spaced more than 50 m apart. Each trap was baited with a pheromone lure (Pherocomps, Mexico City) that was replaced monthly. Moths were collected every wk, counted, and numbers recorded by trap and site. Trapping was conducted for three years from Jan 2009 to Dec 2011, resulting in a total of 102 observation dates.

Statistical Analysis

Data from the first experiment were Box-Cox (Y^0.6) (trial 1) or Ln (x+1) (trial 2) transformed and analyzed using two-way analysis of variance (ANOVA), trap design as the first factor and trap height as the second factor. Data from the experiment that evaluated the effect of trap color were Box-Cox (Y^-0.2) transformed and analyzed by one-way ANOVA. Treatments means were compared with the Tukey test ($P = 0.05$). All statistical analyses were performed using SAS Statistical software.

Results

Influence of Trap Types and Trap Height on Captures of *C. decolora* Males

In the first trial, traps captured 982 males in total. In the second trial, traps captured 1,351 moths. During these trials non-target moths were not captured. In both trials, trap design significantly influenced the captures of *C. decolora* males (trial 1: $F = 6.84$; df = 2, 27; $P < 0.01$; trial 2: $F = 24.59$; df = 2, 27; $P < 0.001$). However, the number of males captured was not affected by trap height (trial 1: $F = 2.34$; df = 2, 27; $P > 0.05$; trial 2: $F = 0.36$; df = 2, 27; $P > 0.05$;Table 1). The interaction term between trap design × trap height was also not significant in both trials (trial 1: $F = 0.75$, df = 4, 27; $P > 0.05$; trial 2: $F = 1.11$; df = 4, 27; $P > 0.05$). In both trials, the water-trap caught more males than the jug trap and the Scentry® *Heliothis* trap. In the first trial, there were no significant differences in the number of males captured by the jug trap and the Scentry® *Heliothis* trap. However, in the second trial, the jug trap caught significantly more males than the Scentry® *Heliothis* trap (Fig. 3).

Table 1. Mean number (± SEM) of males of *Copitarsia decolora* captured to traps placed at three different heights.

Trap height (m)	Trial 1	Trial 2
0.5	22.41 ± 3.6 a	32.5 ± 7.4 a
1.0	35.5 ± 4.8 a	40.3 ± 10.4 a
1.5	23.8 ± 3.9 a	39.8 ± 7.7 a

Means within the same column followed by the same letter are not significantly different, Tukey test ($P = 0.05$).

Influence of Color Trap on the Capture of *Copitarsa decolora* Males

The number of *C. decolora* males caught was significantly affected by the color of the water-trap ($F = 2.89$; df = 4, 27; $P < 0.05$). There were no significant differences in the number of males captured by yellow, blue, brown and green color traps, but green traps captured more males than red traps (Fig. 4). However, the catches of red traps were intermediate between and not significantly different from those captured by yellow, blue, and brown traps (Fig. 4).

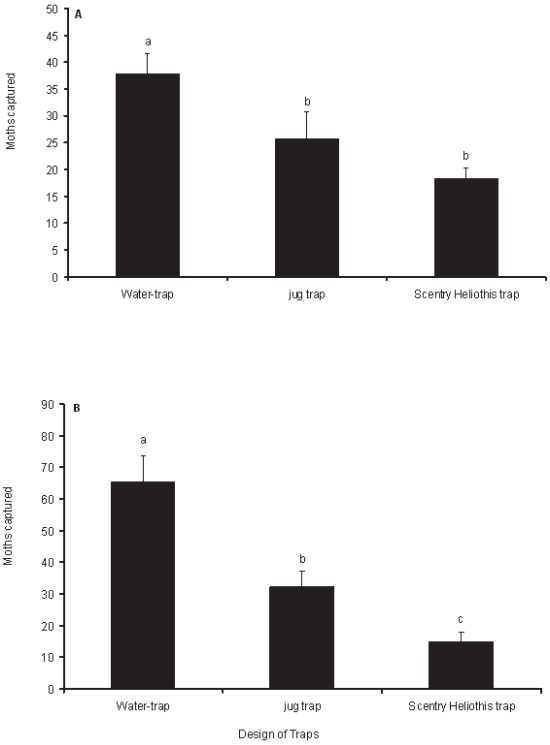


Fig. 3. Mean (+SEM) number of males of *Copitarsia decolora* captured with different traps baited with sex pheromone in trial 1 (A) and trial 2 (B). Traps were replicated 4 times and deployed 17 Oct to 17 Dec 2008 (trial 1) and 23 Jan to 23 March 2009 (trial 2). Significant differences within traps are shown by different letters over the bars (Tukey test, $P = 0.05$).

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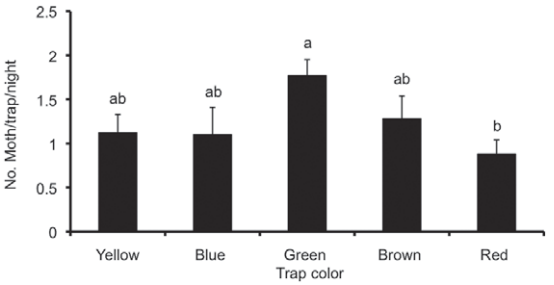


Fig. 4. Mean (+SEM) number of males of *Copitarsia decolora* captured by traps of different color baited with sex pheromone. Traps were replicated 4 times and deployed 11 April to 13 May 2011. Significant differences within treatments are shown by different letters over the bars (Tukey test, P = 0.05).

Seasonal Flight Activity of *Copitarsa decolora*

In the 3 yr of trapping, the overall distribution of trap captures over the season was unimodal, with a distinctive peak in trap catches occurring between Mar and Apr (Fig. 5). A total of 6,978 *C. decolora* males were captured during the 3 yr of trapping. Non-target moths were not caught during this study. A total of 3,278, 2,951, and 749 males were captured in 2009, 2010, and 2011, respectively. Pheromone trap captures decreased by about 75% during 2011 in comparison to 2009 and 2010. The numbers of males captured in the different sites were quite similar, i.e., 2,494, 2,395, and 2,097 individuals caught in Chicosein, La barda, and San Francisco, respectively.

Discussion

The trap design is an essential component in any monitoring or mass trapping system (Wall 1989). In this work, we found that trap design affected the catch of *C. decolora*. The water-traps were more effective than either the Scentry® *Heliothis* trap or the jug trap to capture *C. decolora* males. Several studies have shown that water-traps captured more males in comparison with other trap types in different insect species (Dickerson & Hoffman 1977; Thompson et al. 1987; Downham et al. 2004; Herman et al. 2005). For example, Herman et al. (2005), working with the potato tuber moth, *Phthorimaea operculell*a (Zeller), found that the water-trap caught in average 4 times more males that of the sticky trap and almost 15 times more than the funnel trap. In contrast, Kehat et al. (1981) found that funnel traps baited with synthetic sex pheromone or virgin Egyptian spiny bollworm, *Earias insulana* (Boisduval), females caught significantly more males than water traps baited with the same lures. The water-trap used in this study was cheap, about 3 pesos (US$ 0.23), easy to deploy and maintain, resistant to sun, rain, and strong wind. The jug trap may be considered as a second option to monitoring *C. decolora* in this region. The jug trap is the cheapest of the designs evaluated and the least susceptible to be stolen. However, it is appropriate to consider that the performance of water and jug traps may decline in hot dry weather as the water evaporates (Herman et al. 2005). In our study, drying out of the jug trap occurred during hot days, and this may have affected its performance.

Our study showed that captures of *C. decolora* males were affected by the color of the trap, and green water-traps captured more males than red water-traps. Previous studies with other moth species have shown that color can affect the captures of males in pheromone traps (Mitchell et al. 1989; Lopez 1998; Meagher 2001; Athanassiou et al. 2004). For example, plastic bucket traps with green canopies, yellow funnels, and white buckets all baited with pheromone caught more *Spodoptera* spp. males than all-green or all-white traps (Mitchell et al. 1989; Lopez 1998; Meagher 2001). Athanassiou et al. (2004) found that white traps captured more olive leaf moth, *Palpita unionalis* (Hübner), males than yellow, green, and brown traps.

Trap height, another component evaluated in this study, did not influence *C. decolora* captures. Also, there was no interaction between trap height and the trap design. As in the case of trap design, trap height may or may not influence the capture of males by traps baited with pheromone. Similar to our results, Herman et al. (2005) reported that there was no significant difference on the catch of *P. operculella* males with sticky traps at 0.3 m and 1.0 m. Using funnel traps, Downham et al. (2004) found that more legume pod borer, *Maruca vitrata* F., males were captured at 120 cm than at 20 cm and 170 cm. Malo et al. (2004) reported that the efficiency of Scentry® *Heliothis* traps for capturing fall armyworm, *Spodoptera frugiperda* (J. E. Smith), males was affected by height, whereas the catch of bucket traps was independent of height, suggesting an interaction between trap design and trap height. Perhaps trap height did not affect the captures of *C. decolora* males because all traps were placed above the crop canopy and so the crop did not obstruct the pheromone plume. However, other factors may be involved. For example, Downham et al. (2004) reported that an optimal trap height could reflect the preferred natural flight activity zone of a species.

Capture of *C. decolora* males in the 3 experimental sites was unimodal, the greatest numbers of individuals were captured between Mar and Apr. In contrast, Suárez Vargas et al. (2006), who sampled larvae in cruciferous crops in Acatzingo (Puebla) and Texcoco (state of Mexico) during Nov 2003 to Dec 2004, found that *C. decolora* had 3 population peaks in Jan, Jun, and Nov. Although

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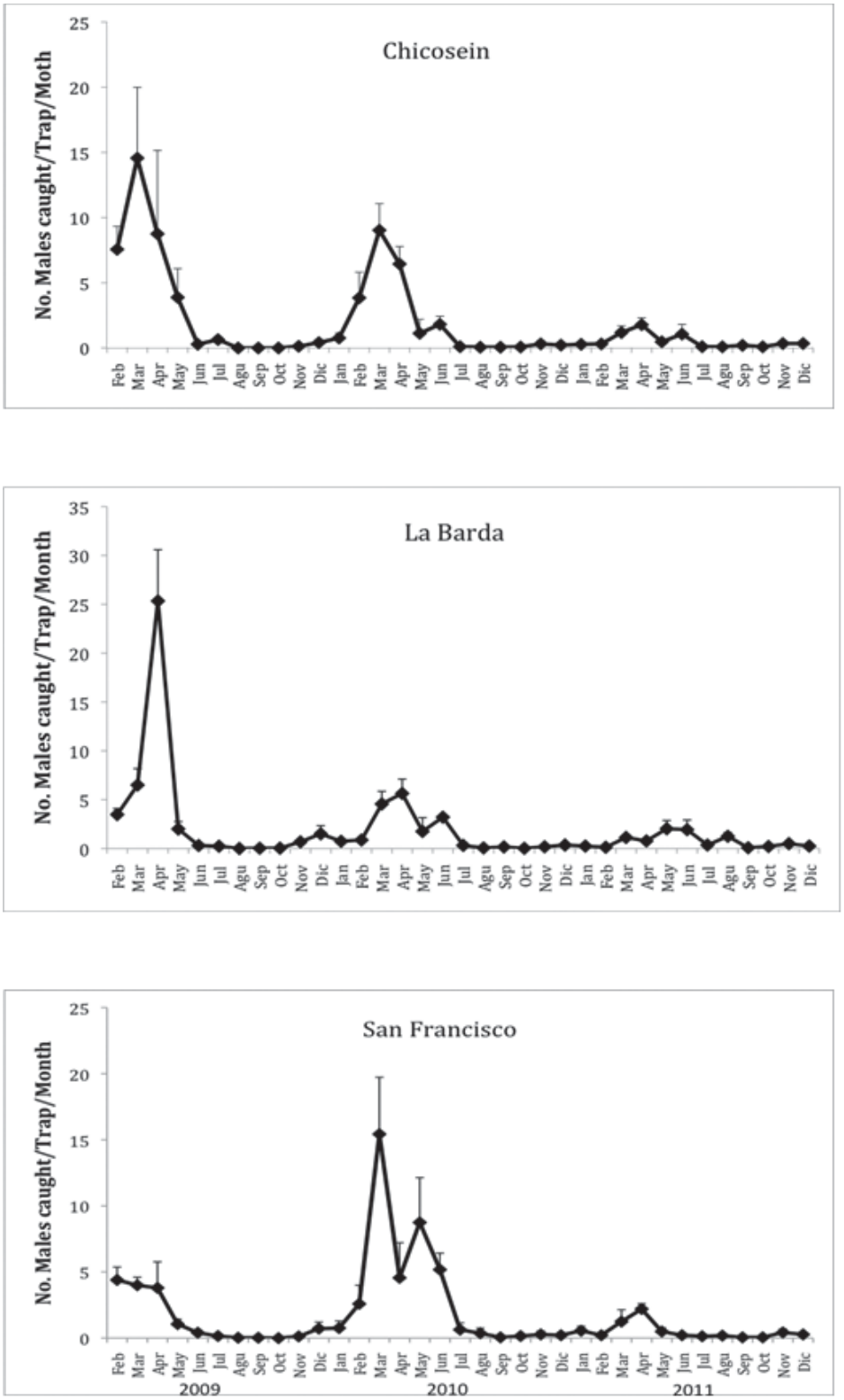


Fig. 5. Seasonal phenology of *Copitarsia decolora* in San Luis Potosi, Mexico. Data are mean (+ SEM) monthly capture of males in pheromone-baited traps during 2009-2011 at three locations in San Luis Potosi.

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the results of both studies cannot be compared because different sampling methods were used, they suggest that there is a geographical variation in the seasonal population fluctuation of *C. decolora*. Also, we found that the captures of *C. decolora* decreased in 2011 with respect to 2009 and 2010. Because the area cultivated with cruciferous crops in the region was the same in the 3 different years, the decrease of *C. decolora* populations during 2011 may be due to environmental factors. For example, the 2011 winter in municipality of Soledad de Graciano Sánchez was colder (2.7 °C) than the winters of 2009 (5.1 °C) and 2010 (4.4 °C), and the low temperatures recorded in 2011 may have killed *C. decolora*. We have found that trap captures were negatively correlated with minim temperatures, but there were no correlations between trap catches and maximum temperatures and precipitation (unpublished data). Gould et al. (2005) have estimated that *C. decolora* populations on asparagus would not develop at temperatures > 31.3 °C or < 6.9 °C.

In conclusion, we found that trap design strongly affected pheromone trap catches of *C. decolora* males; the water-trap performed better than the jug trap and the Scentry® *Heliothis* trap. Trap height had no significant effect on moth catch. Our data strongly indicate that the green water-trap may be a good design for monitoring the populations of *C. decolora* in cruciferous crops in Central Mexico.

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