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Adult population fluctuation of *Comadia redtenbacheri* (Hammerschmidt, 1847) (Lepidoptera: Cossidae)

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Abstract

Comadia redtenbacheri (Hammerschmidt, 1847) is an insect highly regarded for its commercial and nutritional value. Adult fluctuation in a plantation of *Agave salmiana* Otto ex Salm-Dyck was determined using ultraviolet light traps. Trapped adults were counted weekly during three periods (December 2013 to December 2014, December 2014 to December 2015, and December 2015 to June 2016), and temperature and relative humidity were recorded. Adult population was present 157 days on average, from December to May, with peak capture on day 83. The average sex ratio of females to males was 1:14. Average environmental conditions that favoured the highest capture in the three periods were 17.8º C and 47.1% relative humidity. Knowledge of the period of adult presence and the influence of temperature and relative humidity are important for management and conservation of the insect population by farmers and gatherers.
Keywords: Lepidoptera, Cossidae, *Comadia*, ultraviolet light, trapping, Mexico.

Fluctuación poblacional de adultos de *Comadia redtenbacheri* (Hammerschmidt, 1847) (Lepidoptera: Cossidae)

Resumen

Comadia redtenbacheri (Hammerschmidt, 1847) es un insecto muy apreciado por su valor comercial y nutricional. Se determinó la fluctuación de adultos en una plantación de *Agave salmiana* Otto ex Salm-Dyck, utilizando trampas de luz ultravioleta. Los adultos atrapados se contabilizaron semanalmente durante tres períodos (de diciembre de 2013 a diciembre de 2014, de diciembre de 2014 a diciembre de 2015 y de diciembre de 2015 a junio de 2016), en los que se registraron la temperatura y la humedad relativa. La población adulta estuvo presente 157 días en promedio, de diciembre a mayo, con un pico de captura en el día 83. La proporción de sexos promedio de hembras y machos fue de 1:14. Las condiciones ambientales promedio que favorecieron la mayor captura en los tres períodos fueron 17.8º C y 47.1% de humedad relativa. El conocimiento del período de presencia de los adultos y la influencia de la temperatura y la humedad relativa son importantes para el manejo y conservación de las poblaciones de insectos por parte de los agricultores y recolectores.
Palabras clave: Lepidoptera, Cossidae, *Comadia*, luz ultravioleta, captura, México.

Introduction

Comadia redtenbacheri (Hammerschmidt, 1847) (Lepidoptera: Cossidae) is an economically and nutritionally important insect. Due to its high commercial value, it has been overexploited and red worm populations have diminished on agave plants (Ramos-Elorduy, 2006). This situation has generated much interest in protecting and preserving this natural resource in Mexico through controlled production units. However, there is no information on all stages of its life cycle, mainly because most studies have focused on the larval stage in the laboratory and greenhouse (Hernández-Livera et al. 2005; Llanderal-Cázares et al. 2007, 2010).

The species *C. redtenbacheri* is distributed from south-eastern Texas, USA, to Mexico, where it is widely distributed in the states of Guanajuato, Hidalgo, México, Michoacán, Oaxaca, Puebla, Querétaro, Tlaxcala, Zacatecas, Veracruz and Mexico City. Its main hosts are *Agave salmiana* Otto ex Salm-Dyck, *Agave atrovirens* Karw. ex Salm-Dyck and *Agave mapisaga* Trel. (Ancona, 1931; Brown, 1975; Ramos-Elorduy et al. 2011). Information exists on its biology and behaviour (Miranda-Perkins et al. 2013; Llanderal et al. 2017), associated organisms parasitoids (Zetina et al. 2009, 2012; Zetina & Llanderal, 2014) and bacteria (Hernández-Flores et al. 2015), reproduction (Ramírez-Cruz & Llanderal-Cázares, 2015), morphology of all its developmental stages (Castro-Torres & Llanderal-Cázares, 2015, 2016), adult emergence in laboratory (Miranda-Perkins et al. 2016), cultivation by induced infestation in agaves (Delgado-Tejeda et al. 2017; Espinosa-García et al. 2018), bionomics (Llanderal-Cázares et al. 2017) and molecular delineation (Cárdenas-Aquino et al. 2018). However, the biology, behaviour, and ecology of adults has not been studied, and the abiotic factors (temperature, relative humidity and rainfall) that affect its emergence are unknown. Knowledge of these conditions is important to protect the adults in the field and to improve their reproduction under controlled conditions. Moreover, availability of a seasonal resource is important for its management. Yen (2012) mentioned that, regarding coleopterans and lepidopterans that are eaten in their larval stage, there is a lack of information on the different developmental stages and on adults, which has created confusion in the identification of the species.

There are several important methods for sampling insect populations in the field. Light traps are one of the most efficient methods used to determine the behaviour of populations of nocturnal insects (Truman, 1974; Truxa & Fiedler, 2012; Shimoda & Honda, 2013). In most cases, a single light trap is used in or around the sampling site. Through periodic sampling, it is possible to detect the presence of insects and obtain quantitative data on their abundance, which can be used to predict changes in the population and its trend throughout the season (Szentkirályi, 2002). Light traps have been used in several types of studies (Hienton, 1974). Ultraviolet light (UV) traps are used to catch insects belonging to orders such as Coleoptera, Orthoptera, Isoptera and Dictyoptera in India (Ramamurthy et al. 2010) and Lepidoptera from different families such as Noctuidae, Geometridae, Drepanidae and Pyralidae in Austria (Truxa & Fiedler, 2012).

Information on *C. redtenbacheri* adult presence throughout the season is indispensable for its management and conservation, through timely detection to avoid agricultural practices that may affect the adults in their reproductive stages. The objective of this work was to determine the population fluctuation of adults of *C. redtenbacheri* in native populations of *Agave salmiana* and its relationship with temperature and humidity. If last instar larvae emerge from agave plants in September and October (Llanderal et al. 2007), it can be assumed that the adult stage will appear at the end of the year.

Materials and methods

Adult population fluctuation of the agave red worm was recorded in Teotihuacan, State of Mexico (19º 42’07” N and 98º 54’58” W, altitude 2319 m), Cwb climate (subtropical or temperate with dry summers) in an *A. salmiana* plantation (Figure 1), about three years old and 30 cm tall. Density was approximately 10,000 plants/ha, and about one tenth was infested with *C. redtenbacheri* larvae. Distance to the closest town was 612 m. Adult capture was recorded during three periods: **1**) December 2013 to December 2014, **2**) December 2014 to December 2015, and **3**) December 2015 to June 2016, because in previous years we had observed the presence of *C. redtenbacheri* adults as of January, as Nolasco et al. (2002) and Llanderal-Cázares et al. (2007) reported. Two UV traps (ITRAP®, Naucalpan, State of Mexico), designed and modified by ITRAP from the Pennsylvania® type (Frost, 1957), were used. The traps were placed at a height of 1.25 meters so that the catch container would not touch the ground but would stand above the plants. They were distributed 40 m apart in a neighboring lot with dispersed agave plants. The study area, 6522 m^2, was enclosed with a screen to protect the agaves infested by *C. redtenbacheri* , and it was also useful for protecting the traps that remained in the same places throughout the experiment. The traps consisted of four acrylic panels placed at 90º angles to form a square and an LED lamp suspended in the centre. The catch container is a plastic funnel supported by a polyvinyl chloride (PVC) pipe and a collecting bucket with antifreeze (Bardahl®, Toluca, State of Mexico) recommended to preserve trapped insects (Thomas, 2008). The trap was secured to the ground by means of three stainless steel tubes screwed to the funnel. The electrical system of the UV traps works with the energy provided by a 10 w, solar panel (Enesol®, model DS-A18-10, State of Mexico); the energy is stored in a rechargeable 12 volt lithium battery, which has a circuit that regulates the charge to be stored during daylight hours and turns the lamp on at night. Sampling was conducted every week from the date the experiment was set up. Samples were taken to the Insect Physiology Laboratory of the Colegio de Postgraduados, campus Montecillo, State of Mexico. Each sample was placed on absorbent paper to dry. Later, *C. redtenbacheri* adults were identified, using the taxonomic keys of Triplehorn & Johnson (2005). Also, adult females and males were separated and counted, and their morphological traits were corroborated with those reported by Brown (1975) and Castro-Torres & Llanderal-Cázares (2015), who mention bands of scales on the wings that form two whitish inverted V-shaped marks when the moth is in resting position; the body is light brown densely covered with spatulate and filiform scales, serrated antennae on females and bipectinate on males, and atrophied mouthparts.

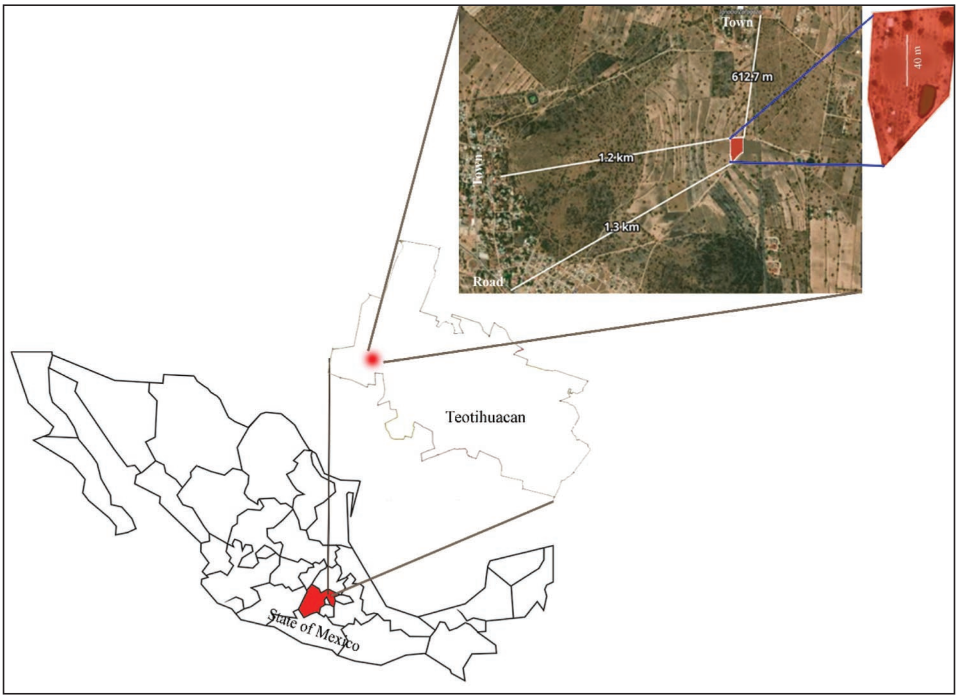

Figure 1. Study area, Teotihuacan, State of Mexico, Mexico.

Temperature and relative humidity were recorded hourly by a data logger, model RHT10 version 5.6 (Extech(r) instruments, United States), placed at the same location as the traps. Daily and weekly averages were calculated. Precipitation data were taken from weather station 15090 in Tecámac, State of Mexico (CONAGUA, 2020).

An analysis of variance was performed with the adults trapped in the three periods evaluated using a completely randomized design. Comparison of means of sex and total adults was conducted with a Tukey test (P=0.05). Pearson's correlation coefficient was calculated during the three sampling periods in the months of highest adult capture with temperature and relative humidity variables (SAS Institute 2015).

Results

The season of adult *C. redtenbacheri* capture during the three evaluated periods was similar, occurring from December to May and lasting an average of 157 days. Capture of males and females was 5163 in the first period, 2023 in the second period, and 1480 in the third period, a total catch of 8666 adults. In this study, the largest catches occurred on day 72 in the first period, on day 92 in the second, and on day 85 in the third. Males were more abundant than females in all the periods, as can be observed in the average capture of the two traps (Figure 2). The average percentages of females and males trapped on all sampling dates was 7.1% females and 92.9% males during the three evaluated periods, with significant differences (α=0.05) in the number of insects trapped in the first period compared with those caught in the second and third. The sex ratio was similar in all periods. Moreover, the total number of insects captured decreased over the sampling periods (Table 1); this could be attributed to the small area of the lot where traps were placed and to the successive captures that may have reduced the insect population. In the first period, the highest peak of adult capture occurred when the temperature reached 20.2º C (Figure 3), followed by capture at 16.3º C (Figure 4) in the second period and at 16.8º C in the third period (Figure 5).

Table 1. Comparisons of means and sex ratios of catches of *Comadia redtenbacheri* adults in the three periods evaluated. SE: Standard error, Pr: Probability, HSD: Honestly Significant Difference, mean in a column with the same letter are not statistically different (P=0.05; Tukey), n= 162.

Periods	Means ± SE Females	Means ± SE Males	Total ± SE Females+Males	Ratio Females:Males
First	7.24± 0.78 a	88.37±9.57 a	95.61±10.28a	1:12a
Second	2.09 ± 0.78 b	35.37±9.57 b	37.46±10.28b	1:17a
Third	2.04± 0.78 b	25.37±9.57 b	27.41±10.28b	1:13a
Pr	<.0001	<.0001	<.0001	<0.9801
HSD	2.57	31.76	34.11	4.6721

When the number of trapped *C. redtenbacheri* adults is correlated with temperature averages using Pearson correlation coefficients during the months of highest capture (January, February, and March) in the three evaluated periods, a statistically significant relationship was found for temperature (r = 0.53, P<0.0001). Correlation of this abiotic factor explains the behaviour and the population fluctuation of this insect; that is, at higher temperatures, catches of *C. redtenbacheri* adults increase and vice versa. During adult capture in the first period, the average relative humidity was lower (46%) than in the second (70%) and third (53%) periods. The largest peaks of capture in each period were found with a relative humidity of 45.5%, 47.1%, and 48.7% for the first, second and third year, respectively. When the number of trapped *C. redtenbacheri* adults is correlated with averages of humidity using Pearson correlation coefficients during the months of highest capture (January, February, March) in the three evaluated periods, a statistically significant relationship was found for relative humidity (r = -0.44, P<0.0001). Correlation of this abiotic factor explains that catches of *C. redtenbacheri* adults decrease at higher relative humidity. The highest capture of adults in traps occurred when precipitation was scarce, and vice versa, during February and March with variation in each of the periods (Figures 3-5).

Discussion

The capture of *C. redtenbacheri* adults occurred from December to May, differing from Llanderal-Cázares et al. (2007), who reported that adults in the field emerged as if the first week of January. In contrast, Miranda-Perkins et al. (2016) mention that in captivity, after observing larvae pupating in September and October, emergence begins in early April and ends by the third week of May, with a duration of 49 days and maximum values of emergence on days 19 and 20.

The number of males was consistently higher than the number of females in each of the periods, and in the laboratory, Miranda-Perkins et al. (2013) reported that last instar larvae and pupae of males are smaller than those of females. Moreover, Miranda-Perkins et al. (2016) also found a sex ratio of 1:1 after larvae with a weight ranging from 0.30 to almost 1.0 g were induced to pupate in a substrate of soil and vermiculite, which in laboratory conditions produces similar proportions of *C. redtenbacheri* individuals of both sexes, according to larva weight. Solomon (1976) observed that in the cossid *Prionoxystus robiniae* (Peck, 1818), the sex ratio was stable from one year to the other over three years, with an average of three males to two females. The lower number of females of *C. redtenbacheri* in the traps could be due to their reduced ability to fly, while the males fly as soon as they emerge, as observed by Solomon & Neel (1973) in *P. robiniae*, who mention that the males have a rapid zigzag flight pattern, while females will remain on the host, near the site of emergence. Also, in *Zeuzera pyrina* (L., 1761) (Lepidoptera: Cossidae), Durán et al. (2004) observed that males have greater mobility than females, whose voluminous abdomens limit their movement. Also, Ramírez-Cruz & Llanderal-Cázares (2015) reported that the female *C. redtenbacheri* is proovigenic and emerges with 104 mature ovocytes ready to be fertilized and oviposited, limiting its flight capacity. This is the characteristic that could have reduced female arrival in the traps.

In *C. redtenbacheri,* the highest adult capture for the three periods was found at an average of temperature of 17.8º C and 47.1% relative humidity, and consistently, as temperature increased, relative humidity diminished, and vice versa. The effect of abiotic factors on the populations has previously been discussed in other species of insects, with behaviour similar to that found in *C. redtenbacheri*. For example, in *Chilo partellus* (Swinhoe, 1885) (Lepidoptera: Crambidae), several temperatures and relative humidity percentages were evaluated to determine the interval of these factors in which the species develops better (Tamiru et al., 2012). Another example of the importance of these two factors, *Z. pyrina*, is reported by Ismail et al. (1992), who showed that temperature and relative humidity were the main environmental conditions that influenced adult activity. Zada et al. (2014) found that temperature and relative humidity are paramount to fluctuations in population distribution and abundance of *Cydia pomonella* (L. 1758) (Lepidoptera: Tortricidae). In the first period, the highest adult peak of capture occurred when the temperature reached 20.2º C, followed by 16.3º C and at 16.8º C, suggesting that the ideal temperature for *C. redtenbacheri* capture is found within this range. Miranda-Perkins et al. (2013) mention that in the laboratory *C. redtenbacheri* adult emergence was higher when no moisture was applied to the substrate, coinciding with data found in the field since, in all three years, capture was inversely proportional to the level of environmental humidity.

The efficacy of UV light traps enabled determination of *C. redtenbacheri* population fluctuation in the three evaluated periods, as has been shown with a large number of nocturnal insects that can perceive light radiation, especially in the region near 320-380 nanometers (Hienton, 1974; Shimoda & Honda, 2013). The use of UV traps has been successful in several species of insects, mainly agricultural and forest pests (Szentkirályi, 2002; Al-Deeb et al. 2012; Nielsen et al. 2013; Sermsri &

Torasa, 2015). In later studies, it would be useful to increase the number of traps and rotate their positions as well as to increase the study area.

Knowledge of the capture period of adults is important for producers and gatherers. Care and protection of this species from December to May, the most vulnerable season for reproduction of the insects, will enable them to increment populations and to better use and conserve the species. The insect's attraction to UV light traps can be useful to determine whether there are populations of *C. redtenbacheri* in an area and their abundance. The influence of temperature and relative humidity must be considered to manage the insect under possible production systems.

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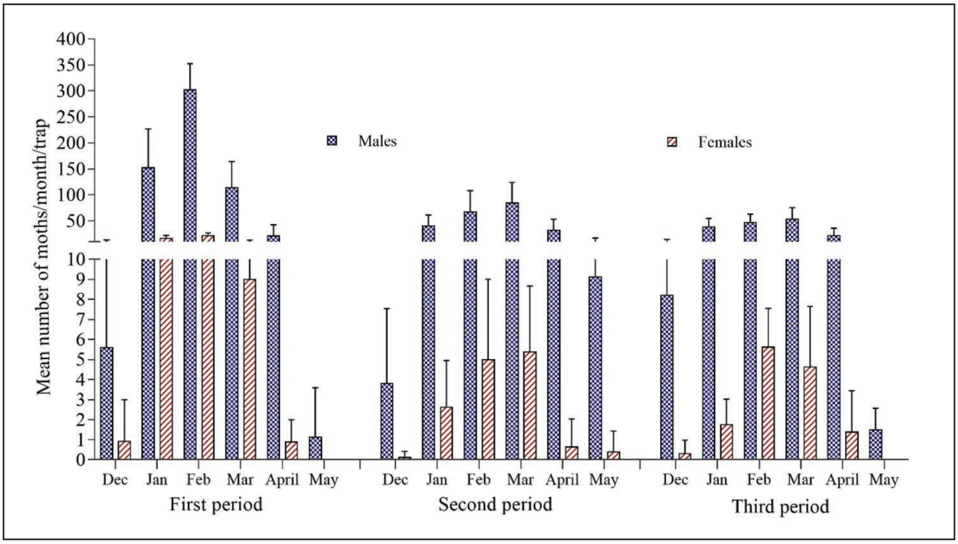

Figure 2. Average capture of moths during the three periods of evaluation. Teotihuacan, Mexico.

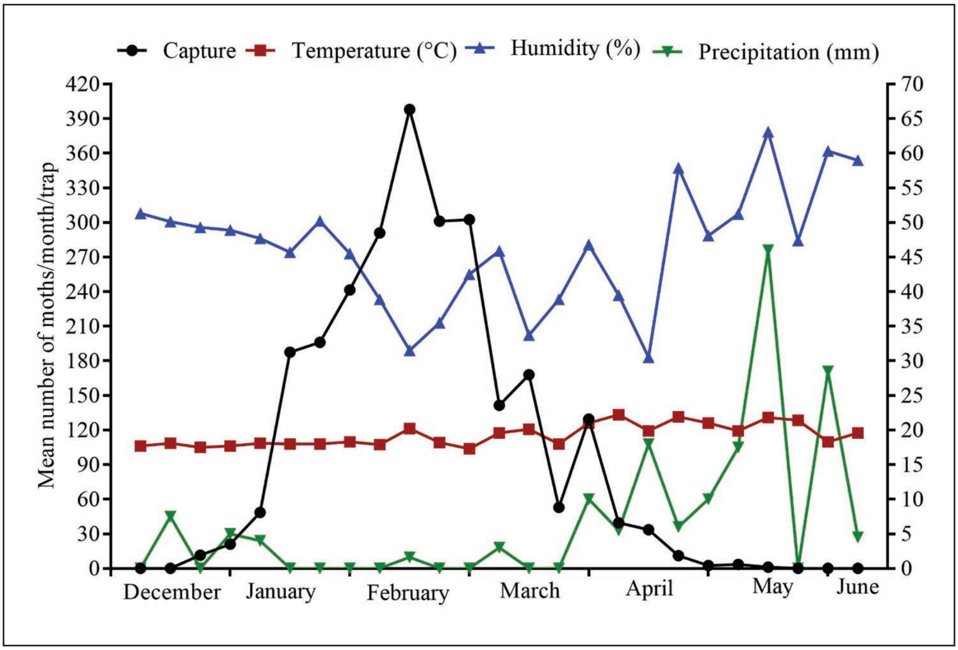

Figure 3. Average weekly capture of adult *Comadia redtenbacheri* in two light traps during the first period.

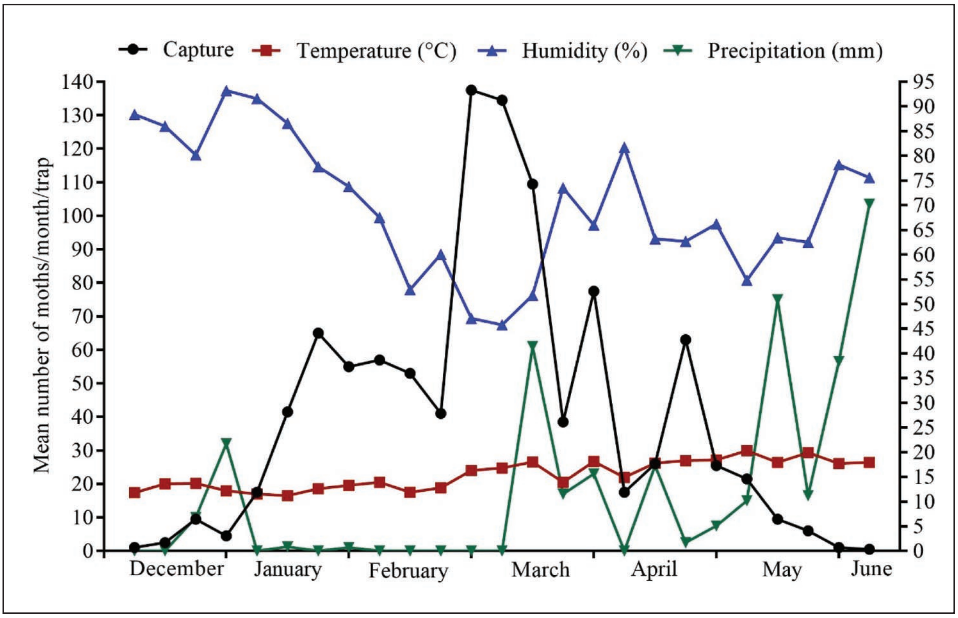

Figure 4. Average weekly capture of adult *Comadia redtenbacheri* in two light traps during the second period.

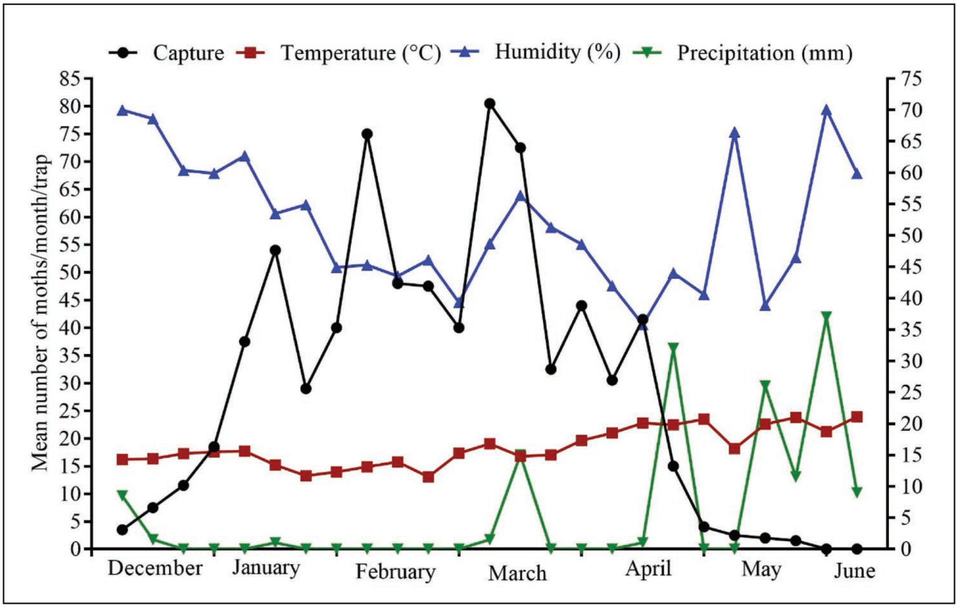

Figure 5. Average weekly capture of adult *Comadia redtenbacheri* in two light traps during the third period.