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Logistic regression analysis to predict parasitism in larvae of *Comadia redtenbacheri* Hammerschmidt (Lepidoptera: Cossidae).

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Abstract

Zetina DH, Llanderal-Cázares C, De los Santos-Posadas HM. 2011. Logistic regression analysis to predict parasitism in larvae of *Comadia redtenbacheri* (Lepidoptera: Cossidae). Entomotropica 26(1): 1-6.

The agave red worm *Comadia redtenbacheri* Hammerschmidt. (Lepidoptera: Cossidae), used as food in its larval stage, is a profitable natural resource in Mexico. As part of the quality control required to establish stock for rearing this insect, a risk model using qualitative and quantitative variables was generated to determine the probability of the larvae becoming infested by parasitoids. The variables that were most significant in generating the model were larval weight and position of the lesion on the larvae caused by the parasitoid. There is a greater possibility that a small larva with a ventral or lateral lesion, or with both lesions, is parasitized.

Additional key words: Agave red worm larvae, edible insects, parasitoids

Resumen

Zetina DH, Llanderal-Cázares C, De los Santos-Posadas HM. 2011. Analisis de regresión logística para predecir el parasitismo en larvas de *Comadia redtenbacheri* (Lepidoptera: Cossidae). Entomotropica 26(1): 1-6.

El gusano rojo del maguey *Comadia redtenbacheri* Hammerschmidt. (Lepidoptera: Cossidae) es un recurso natural rentable en México, ya que se usa como alimento en su fase larval. Como parte del control de calidad requerido para establecer un pie de cría de este insecto, se generó un modelo de riesgo para conocer la probabilidad de infestación de la larva por parasitoides, mediante el uso de variables cualitativas y cuantitativas. Las variables que tuvieron mayor significancia para generar el modelo fueron el peso de la larva y la posición de la lesión causada por los parasitoides, ya que existe mayor probabilidad de que una larva de menor peso que presente una lesión ventral, lateral o ambas, se encuentre parasitada.

Palabras clave adicionales: Gusano rojo del Maguey, insectos edibles, parasitoides.

Introduction

Comadia redtenbacheri Hammerschmidt, 1848 (Lepidoptera: Cossidae) is a species of commercial interest used as food in several regions of the Mexican high plateau (Dampf 1927, Ramos 1982, Ramos et al. 1984, Ramos-Elorduy et al. 1998). It is found naturally and is collected to be consumed in both rural households and restaurants, as well as in the mescal industry to add value to this alcoholic beverage (Ramos-Elorduy and Pino-Moreno 2001, Ramos-Elorduy 2006, Ramos-Elorduy et al. 2007). The high market demand for this insect has caused overexploitation and, consequently, has decreased populations, causing higher costs and making it less accessible. This situation has motivated studies that aim for intensive production (Llanderal-Cázares et al. 2009). Survival rates in natural populations of the agave red worm are affected by the presence of dipteran and hymenopteran endoparasitoids, which compromise the success of production programs (Zetina et al. 2009). Rearing *C. redtenbacheri* should begin with mature, healthy larvae, and the implementation of an intensive production system requires knowledge of the probability of their infestation by parasitoids, at the individual and population levels. An agave red worm larva in good condition will have a higher probability of reaching its adult stage and reproducing.

Logistic regression analysis is a widely used technique for the study of discrete variables and risk analysis. Its objective is to model the probability that an event will occur (probability of failure 0 or success 1) on the basis of diverse factors and their magnitude, and how the event depends on the other variables (Agresti 2002). Logistic regression is useful for analyzing data in clinical and epidemiological research, for example, to compare the efficacy of different treatments on degrees of infestation (Barón-López and Téllez-Montiel 1995, Boggio 1997). This model has also been used to evaluate chemical products such as insecticides in controling diverse pests (Miller and Miller 1993) and to predict mortality of trees damaged by fire and to determine the probability that they become colonized by different genera of bark beetles (Fonseca et al. 2008).

The objective of this work was to generate a risk model to calculate the probability of parasitism in *C. redtenbacheri* larvae based on a number of quantitative and qualitative criteria.

Materials and Methods

In the State of Mexico, 31 maguey (agave) plants were collected in the municipality of Hueypoxtla, located at the coordinates lat 20°00'45"N, long 99°02'34"W, at an altitude of 2 494 m. Another 31 commercial samples were obtained from vendors selling larvae on the Tulancingo-Otumba highway. A total of 1 200 larvae were obtained from the two samples. Each larva collected was measured and the following quantitative and qualitative characteristics were recorded: origin of the sample, color, consistency, instar, and position and type of lesion present on the body of the larva.

To determine parasitoid infestation in individual specimens, 1 200 individuals from both sample origins were dissected, and measurable external and internal evidence was taken into account: presence, type and number of parasitoids, signs and evident symptoms, weight of each individual. Other external characteristics were also noted, such as coloring (Class 1: white larva; Class 2: pink larva; Class 3: red larva), body consistency (Class 1: turgid; Class 2: soft; and Class 3: fragile), lesions (position: front, middle, back; ventral, lateral, dorsal), and spots that might be present (Class 0: absence of lesions; Class 1: lesion caused by a parasitoid, a dark melanotic spot with an orifice where the parasitoid entered; Class 2: melanotic scratch-like lesion without orifice; Class 3: superficial lesion caused by pathogenic agents). All the characteristics measured of each larva (weight, coloring, body consistency, lesion location, melanotic spot presence) were included in the linear module of a logistic regression model. Only those characteristics significant at a 0.05 probability were included in the model and then eliminated in the classic backward procedure were the least significant variable is excluded until all the variables enter the model at the 0.05 probability. The model was fitted using PROC GENMOD, SAS Institute (1997). With this model it is possible to estimate the probability that a *C. redtenbacheri* larva being parasitized, based on qualitative (e.g. type of coloring, presence/absence of a body lesion,

Table 1. Estimated parameters for the risk model of parasitism in *Comadia redtenbacheri.*

Parameter	Independent Variable	df	Estimated parameter	Standard error	Wald's Chi^2	Pr > Chi^2
β_0	Intercept	1	-2.3767	0.2652	80.3241	<.0001
β_1	Weight (p)	1	-4.133	0.7661	29.1017	<.0001
β_2	Ventral (V)	1	1.7207	0.2899	35.2319	<.0001
β_3	Lateral (L)	1	2.1122	0.2837	55.4331	<.0001

as well as the location of the lesion) and quantitative characteristics (weight) present in each individual (Hernández-Livera et al. 2005).

Results

Once the least significant variables were eliminated, the logistic model only included larval weight and position of lesions with the following structure:

$$P = \frac{exp(\beta_0 + \beta_1 p + \beta_2 V + \beta_3 L)}{1 + exp(\beta_0 + \beta_1 p + \beta_2 V + \beta_3 L)}$$

where P is the parasitism probability value between 0 and 1; β_j is the coefficient of regression of the j^{th} independent variable; p is the weight of the red worm in grams; L is the dichotomous variable equal to 1 if there is at least one lateral lesion, 0 if not; V is the dichotomous variable equal to 1 if there is at least one ventral lesion, 0 if not. The presence of a lesion increases the probability that an agave red worm has been parasitized. In Table 1 the fit of the logistic model can be observed the variables: weight (p) and the presence of a ventral (V) and/or a lateral lesions (L) are all highly significant. The negative sign for the intercept and the β_i parameter indicate that the event has a higher probability of success (being parasited) when weight is low. Furthermore, a lateral lesion has a greater effect than a ventral lesion, according to the success of the event; the effect will increase if both types of lesion are present in the same individual.

In Figure 1, it can be observed the additive effect of weight and lesions on a worm. The presence of a lateral lesion increases the probability that an individual is parasitized, and probability is higher if both types of lesions are found in the same larva.

Discussion

Insects can exhibit different types of lesions caused by diverse agents (Figure 2). Feener and Brown (1997) mention that the ovipositor of the females of the Ichneumonidae family will cause small lesions in the host when the eggs are deposited into the larvae. In contrast, the Tachinidae family includes species called external parasitoids; the larvae of these species cause greater damage at the points of entry in the host larvae by penetrating and breaking the tissues (Clausen 1972, Stireman et al. 2006).

A very small larva (0,009 g) with a lateral lesion has a higher probability to harbor a parasitoid than one without a lesion (42% against less than 10%). If the lesion is ventral, the probability that the larva is parasitized is 33% if it weighs less than 0,6 g, while if the two lesions are present in an individual weighing less than 0,6 g, the probability is 80%. Obviously, probability of parasitism decreases considerably in individuals that do not exhibit lesions (<10%).

Preference of the parasitoids for young larvae is explained by Clausen (1972) who states that the life of the host must be long enough for the parasitoid to complete its development. Bradleigh (1984), however, believes that the

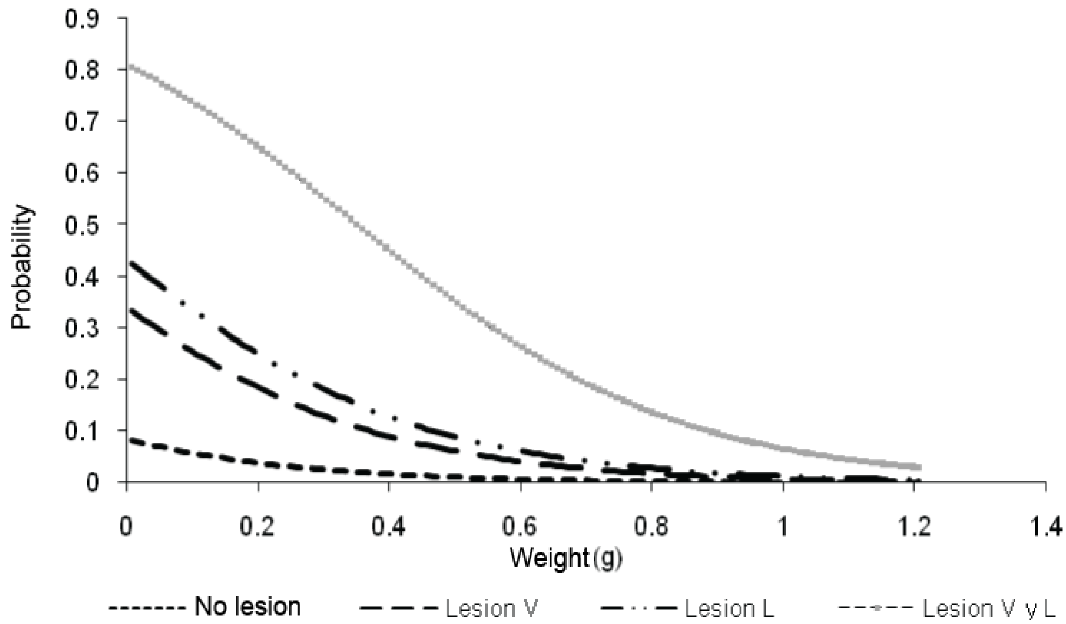

Figure 1. Risk probability of parasitism in *Comadia redtenbacheri* larvae as a function of weight and position of lesions. Lesion V, ventral lesion; Lesion L, lateral lesion; Lesion V and L, ventral and lateral lesions.

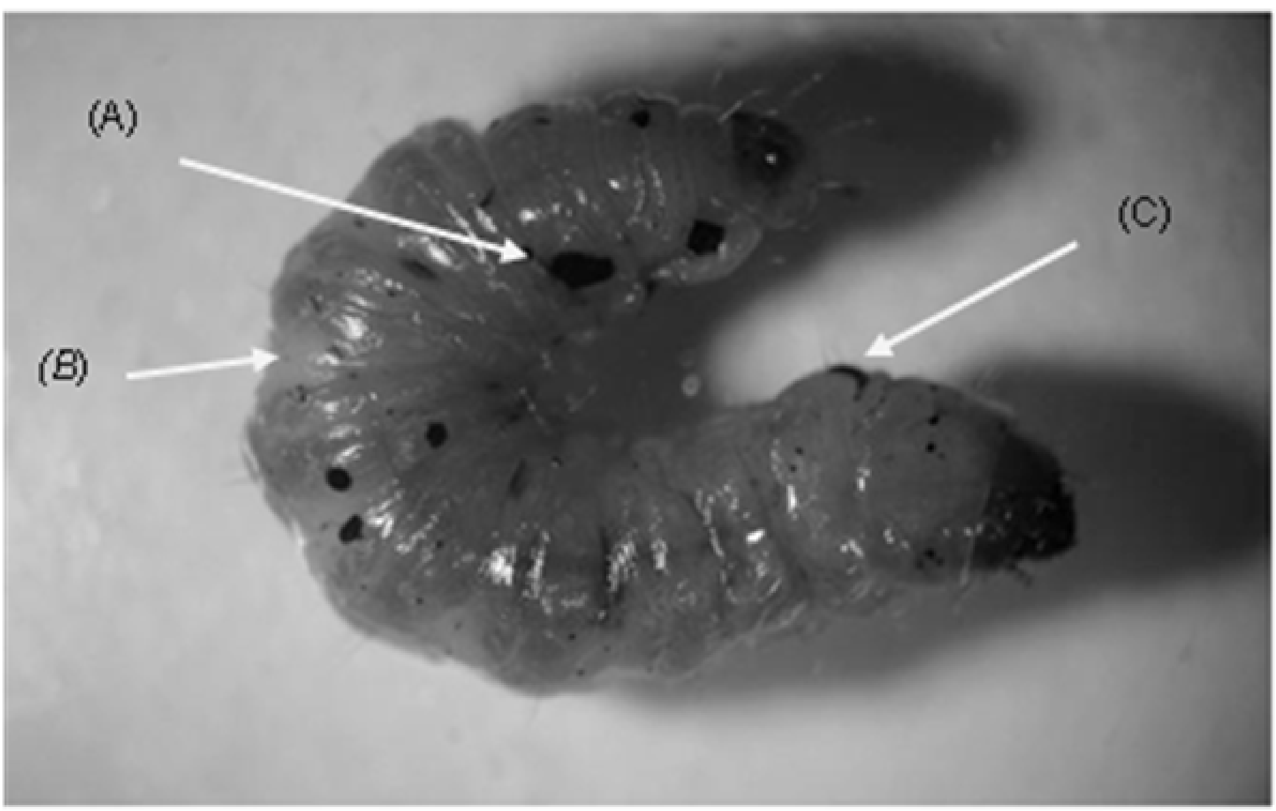

Figure 2. Different lesions in a *Comadia redtenbacheri* larva can be caused by parasitoids (A), pathogens (B), injury or friction (C) among other.

selection of the parasitoid is based on the host's physical characteristics and the chemical compounds emanated by the host.

The value of the agave red worm increases constantly as it becomes more and more scarce. During its annual life cycle, it undergoes depredation by gatherers who destroy the agave plant where it is found. Moreover, manipulation of the insect during gathering contaminates the populations (Ramos 1982). It is therefore necessary to find procedures that involve fewer losses in materials, costs and time. A risk model that predicts whith high probability if a larva is or is not parasitized can improve selection of quality material for breeding stock. Rearing should begin with larvae selected on the basis of their development and other characteristics. Selected larvae should be then placed in trays with soil for pupation to obtain adults that will mate and lay eggs (Llanderal-Cázares et al. 2009).

The risk model generated based on weight and type of lesion permits calculating the likelihood that *C. redtenbacheri* larvae are parasitized. The principal related lesions are ventral and lateral with presence of a melanotic spot and an orifice indicating the parasitoid's entry point. By selecting mature, healthy larvae, it is possible to improve the use of agave red worm populations for selection of breeding stock.

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