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Biological characteristics of the cassava mealybug *Phenacoccus manihoti* (Hemiptera: Pseudococcidae)

Características biológicas del piojo harinoso de la yuca, *Phenacoccus manihoti* (Hemiptera: Pseudococcidae)

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Abstract: The cassava mealybug *Phenacoccus manihoti* (Hemiptera: Pseudococcidae) feeds by sucking the sap of cassava plants, causing damage directly by sucking the sap and contaminating the plant with its toxic saliva and indirectly by favoring the development of sooty molds. To establish an integrated pest management program, information about the biology of pest species is basic. Thus, the objective of this study was to determine some biological characteristics of *Ph. manihoti* on cassava. The experiment was conducted using Santa Helena cultivar which was kept in a semi-heated room at an average temperature of 25 °C. Approximately 20 newly oviposited eggs were placed on four apical leaves of each plant. After the eggs had hatched, only one first-instar nymph was left per leaf. The mealybug nymphs were examined on a daily basis; information on molting time was recorded and data on mortality and oviposition were used to construct a fertility life table. The experiment was conducted with 90 replicates. The average duration of the egg, first-instar, second-instar, third-instar nymph and the adult stages were 7.7, 6.9, 4.9, 5.7 and 20.7 days, respectively. On average, the total life cycle lasted 45.22 days, and each female was able to produce a total of 247 eggs. The net increase rate (R_o), mean generation time (T), intrinsic rate of increase (r_m) and doubling time (D_T) were 223.640 female/female, 36.500 days, 0.145 female/female/day and 4.780 days, respectively. The maximum rate of population increase occurred on the 36th day.

Key words: Fertility life table. *Manihot esculenta*. Insect pest of cassava.

Resumen: El piojo harinoso de la yuca, *Phenacoccus manihoti* (Hemiptera: Pseudococcidae), se alimenta por succión de la savia de las plantas de yuca, causando daño directo por la succión de la savia y la toxicidad de la saliva e indirectamente, favoreciendo el desarrollo de fumagina. Para el establecimiento de un manejo integrado de plagas, es importante conocer la biología de este insecto. Por lo tanto, el objetivo de este estudio fue determinar las caracteristicas biológicas de *Ph. manihoti* en la yuca. El experimento se realizó con el cultivar Santa Helena. Las plantas se mantuvieron en un sitio semi-climatizado con una temperatura media de 25 ºC. Se colocaron aproximadamente 20 huevos recién depositados en las cuatro hojas apicales. Después de la eclosión de los huevos, se dejó una sola ninfa del primer instar por hoja. Las cochinillas se evaluaron diariamente, registrando el tiempo de muda y la mortalidad de las ninfas y la fecundidad y la longevidad de las hembras adultas. A partir de los datos biológicos obtenidos, se realizó la tabla de vida de fertilidad. El estudio tuvo 90 repeticiones. La duración del huevo, ninfa del primer instar, segundo instar, tercer instar y longevidad de la hembra adulta fueron 7,7; 6,9; 4,9; 5,7 y 20,7 días, respectivamente. El ciclo de vida fue de 45,22 días, y la fecundidad fue de 247 huevos por hembra. La tasa reproductiva neta (R_o), tiempo generacional medio (T), tasa intrínseca de crecimiento (r_m) y el tiempo de duplicación (D_T) fueron 223,640 hembras/hembras, 36,500 días, 0,145 hembras/hembras/día y 4,780 días, respectivamente. La tasa máxima de aumento de la población fue en el día 36.

Palabras clave: Tabla de vida y fertilidad. *Manihot esculenta*. Insectos plagas de la yuca.

Introduction

Cassava, *Manihot esculenta* Crantz (Euphorbiaceae) is the staple food of nearly a billion people (FAO/IFAD 2000). In Africa, it is the main source of calories for 65% of the population and an important food for fighting hunger (FAO/IFAD 2005).

In 2011, Brazil produced 27 million tons of cassava and was the largest cassava producer in South America, producing 75% of the crop of this continent (SEAB 2011). The southern central region of Brazil is dominated by industrial agricultural production and has more starch factories than any other region in the country (Groxko 2012). However, with great technological advances in production came problems with new pests and disease, most likely reflecting the environmental imbalance caused by the indiscriminate use of agrochemicals and increased planting areas (Takahashi 2002).

Mealybugs are one of the main pests of cassava. Until recently, approximately 15 species were reported to be associated with the cassava crop, but a recent study provided a taxonomic key to separate 27 species that have been reported affecting *Manihot* spp., of which 24 have been reported on *M. esculenta* (Parsa *et al.* 2012). *Phenacoccus manihoti* Matile-Ferrero, 1977 and *P. herreni* Cox and Williams, 1981 (Hemiptera: Pseudococcidae), both of tropical origin, are the most important species in Brazil (Bellotti *et al.* 1999; 2012).

Commonly known as mealybugs due to the waxy secretion that covers the body of the insect, these mealybug species are usually found on the underside of leaves of the plant canopy, especially around the main veins (Calatayud and Le Rü 2006). The first-instar nymph is quite mobile; in the remaining instars, their movement on the plant is limited. Mealybugs associated with cassava may reproduce by

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parthenogenesis (e.g., *P. manihoti*) or by sexual reproduction (e.g., *P. herreni*) (Bellotti *et al.* 2012).

All nymphal stages and the adult female of *Ph. manihoti* damage the cassava plant directly by sucking the sap and contaminating the plant with its toxic saliva and indirectly by favoring the development of sooty molds (Bellotti *et al.* 1999). As a result, the plants experience reduction in their photosynthetic rate, compromised root quality. In cases of severe attacks yield losses may be as high as 58% (Schulthess *et al.* 2009).

Very little information is available on the biological characteristics of *Ph. manihoti* in Brazil, and studies are needed to learn more about the cultivars and varieties grown in the southern central region of the country. A production management plan is needed for this region; therefore, knowledge of the biological characteristics of *Ph. manihoti* is critical. Accordingly, the objective of the present study was to determine the biological characteristics of *Ph. manihoti* on cassava.

Materials and methods

Plant source. The species studied is associated with cassava plants of the cultivar Santa Helena, the most planted cultivar in the southern central region of Brazil. These plants were grown in semi-climatized greenhouses (25 ± 2 °C and a photoperiod of 14 h). Cassava cuttings were planted in an upright position in 4 L pots containing soil with 10% organic compost. The plants were maintained in a greenhouse and watered daily. When the plants had eight fully developed leaves, they were used for the experiment according to the methodology described by Rheinheimer *et al.* (2009).

Insect source. Mealybugs, *Ph. manihoti* were obtained from infested areas in the city of Santa Mônica /PR (26°06'30"S 53°06'31"O) and maintained in mass rearing facilities at the Biological Control Laboratory of the State University of West Paraná (UNIOESTE), Marechal Cândido Rondon, PR, Brazil.

Experiment procedure. To evaluate the biological characteristics of *Ph. manihoti*, females were separated in trays (29.0 cm long x 20.5 cm wide x 10.0 cm height) for the collection of eggs with a known age. On average, 20 eggs were placed on an apical leaf of a cassava plant. After the eggs hatched, one nymph was left per leaf; and the rest of the nymphs were removed. The mealybugs were observed on a daily basis until their life cycle was completed and information on the time of molting and mortality was recorded for each life stages. Adult females remained on the leaves. On a daily basis, fecundity of the adult females was determined by removing and counting the eggs present under the females using a stereoscopic microscope. Observations were performed on 90 insects, with each insect representing a repetition.

The duration and viability of the egg and nymphal stages and the pre-oviposition period and longevity and fecundity of the females were evaluated. A fertility life table was constructed from the biological data obtained. In the fertility life table was determined the net reproductive rate or number of female offspring (R_o), the mean generation time (T), doubling time or the time required for the population to double in number (D_T), the intrinsic rate of increase or the innate ability to increase (r_m) and the maximum rate of population growth, using the formulas suggested by Silveira Neto *et al.* (1976) and Krebs (1994):

$$R_o = \sum l_x m_x$$
$$T = (\sum l_x m_x x) / (\sum l_x m_x)$$
$$R_m = \log R_o / T \;.\; 0.4343$$
$$D_T = \ln(2) / r_m$$

where, x is the age of individuals in days, l_x is the age-specific survival, and m_x is the age-specific number of female offspring.

The maximum rate of population growth is when the lines of specific fertility (m_x) and survival rate (l_x) intersect in a graph.

Table 1. Number of insects (N), duration (mean ± standard deviation) and viability (%) of the different stages of development, fecundity and longevity of *Phenacoccus manihoti* reared on cassava plants of the cultivar Santa Helena. Marechal Cândido Rondon, PR, Brazil, 2010.

Stage	N	Duration (days)	Survival rate (%)
Egg	94	7.7 ± 0.06	95.75
1st instar	90	6.9 ± 0.14	100.00
2nd instar	90	4.9 ± 0.17	100.00
3rd instar	90	5.7 ± 0.17	96.66
Egg-Adult	94	25.2 ± 0.22	92.55
Pre-oviposition	87	6.2 ± 0.17	97.70
Oviposition	85	14.6 ± 0.57	-
Longevity	85	20.7 ± 0.58	-
Life cycle	85	45.22 ± 0.67	-
Fecundity	85	247.1 ± 13.821	-

[1] average number of eggs female^{-1}.

Results and discussion

The egg stage lasted 7.7 days on average and 95.74% of the eggs were viable. *Phenacoccus manihoti* has three nymphal stages with average durations of 6.9, 4.9 and 5.7 days, respectively (Table 1). Similar results were found by Minko (2009) in the Bonoua cultivar (in Africa) grown at 25 °C, with average durations of 8.0, 6.5, 5.0 and 5.5 days for the egg stage, first, second and third-instar nymph, respectively. Similar values were also obtained by Bellotti *et al.* (1984) in Colombia for females of *Ph. herreni* grown in a greenhouse (28.0 °C to 38.2 °C) containing cassava of the Mcol 113 cultivar; the first, second and third-instar nymph of this species lasted 7.7, 5.1 and 5.6 days, respectively. However, the embryonic development of this species was shorter (6.3 days), most likely due to the higher temperature used in the study.

The nymphal stages lasted on average 17.5 days and the survival rate was 92.6% (Table 1). These results agree with those obtained by Le Rü and Fabres (1987) who reported that the three nymphal stages (first-, second- and third-instar nymph) of *Ph. manihoti* lasts 18.5 days and is characterized by a viability of 91.7%. The life cycle lasted 45.2 days (Table 1), which was similar to that reported by Bellotti *et al.* (1984) for *Ph. herreni* (49.5 days) and *Ph. gossypii* (46.94 days).

The average longevity of the female was 20.7 days; the average pre-oviposition period lasted 6.2 days and the average oviposition period lasted 14.6 days. Fecundity ranged

Table 2. Life and fertility table of *Phenacoccus manihoti* reared on cassava plants of the cultivar Santa Helena. Marechal Cândido Rondon, PR, Brazil, 2010.

Parameters	Results
Net reproductive rate (R_o)	223.64 ♀/♀
Mean generation period (T)	36.50 d
Intrinsic rate of natural increase (r_m)	0.145 ♀/♀/d
Doubling time (D_T)	4.78 d

from 37 to 497 eggs/female with an average of 247.1 eggs/female (Table 1). The pre-oviposition period found in this study was lower than that observed by Le Rü and Fabres (1987); who reported an average pre-oviposition period of 7.4 days and an average fecundity of 387 eggs/female. Bellotti *et al.* (1984) found that *Ph. herreni* females had a similar pre-oviposition period (6.4 days) but a higher longevity (24.8 days) and higher average fecundity (773 eggs/female), these results evidence that *Ph. herreni* has greater potential for population increase than *Ph. manihoti.*

The net reproductive rate (R_o) obtained for *Ph. manihoti* was 223.64 female/female; in other words, given the parthenogenetic reproduction of this species, its population can increase by 223.64 individuals per generation. The average generation period (T) of this species was 36.5 days and the intrinsic growth rate (r_m) was 0.145 female/female/day. The time required for the population to double in number (D_T) was 4.78 days (Table 2).

Le Rü and Fabres (1987) found different values for Ro and r_m (355 female/female and 0.155 female/female/day, respectively) than those obtained in this work; however, their T value was similar (37.9 days).

The maximum rate of population increase, i.e., the meeting point between specific fecundity (mx) and survival rate (lx), occurred at 34.5 days (Fig. 1). This date was earlier than that obtained by Le Rü and Papierok (1984) who found a maximum rate of population increase at 36 days.

During the first week of oviposition, *Ph. manihoti* deposited an increasing number of eggs (on average 4.5 eggs more each day), reaching a maximum peak of 32 eggs per female on the seventh day. After this period, oviposition decreased by 17 eggs per female in the subsequent two days. The females experienced a peak in oviposition between 31 and 37 days and 55.4% of the eggs were deposited during this period (Fig. 1). Le Rü and Papierok (1984) similarly observed a peak in oviposition between 33 and 40 days during which 53.6% of the eggs were deposited.

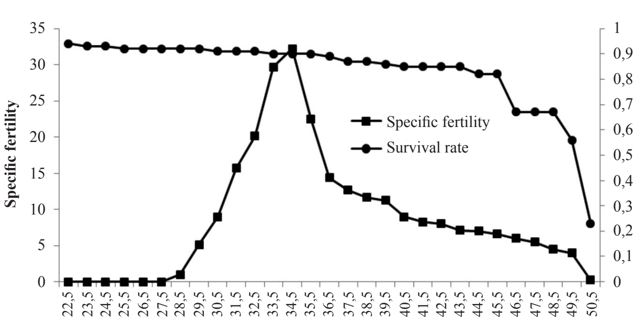

Figure 1. Relationship between specific fertility (mx) and survival rate (lx) of *Phenacoccus manihoti* maintained on cassava plants of the cultivar Santa Helena. Marechal Cândido Rondon, PR Brazil, 2010.

The survival rate of the adult female was 82-92% during the first 18 days after the beginning of oviposition; the survival rate decreased drastically in subsequent days (Fig. 1).

In general, the data obtained in this study were similar to those found by Le Rü and Fabres (1987), Minko (2009) and Bellotti *et al.* (1984).

In this study, *Ph. manihoti* experienced large population increases when reared on the Santa Helena cassava cultivar. From September to February, the period during which this insect is usually present in the field, up to five generations can be produced at average temperatures in southern central Brazil. Considering that *Ph. manihoti* was able to increase its population 223.64 times every generation, in five generations, if there were no mortality factors (predators, pathogens, parasitoids and others), an estimated population of two billion offspring could be produced by each female in a single crop cycle. These values explain why, in the second regrowth cycle (when climatic conditions are favorable to the mealybug), the population of *Ph. manihoti* increases in a short period of time and induces a strong curling on the host plant.

The reproductive potential and the damages caused by *Ph. manihoti* may vary depending on the cultivar or variety of cassava on which the insect develops (Tertuliano *et al.* 1993; Calatayud 2000). For this reason, studies on the most common cultivated varieties in the region are needed. Knowledge acquired in these studies could provide information to producers on which cultivars or varieties are more resistant to this pest and which should therefore be used for planting.

In addition, the maintenance of native natural enemies in these areas is essential, as predators can limit population increases and keep the insect population at levels below those that cause economic damage, thus avoiding the need to adopt other control methods (mainly chemical) and reducing costs and environmental contamination.

Conclusions

Based on this study, *Ph. manihoti* completes its life cycle in approximately 45 days. Over 90% of the eggs are viable and fecundity exceeds 240 eggs/female. These findings demonstrate that the Santa Helena cassava cultivar promotes the development of this species, allowing for a population increase of more than 200 individuals in every generation and resulting in significant damage to cassava crop.

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