The influence of constant temperature on population growth rates of the cassava mealybug, *Phenacoccus manihoti*

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Abstract

Life table studies were conducted to assess the effect of constant temperature on the rate of population growth of the cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero. Four temperatures, between 20 and 30.5 °C, were tested. An inverse relationship was observed between temperature and most demographic parameters.

The intrinsic rate of natural increase (r_m) increased from 0.1 at 20 °C to 0.2 at 27 °C and 30.5 °C. The net reproductive rate varied between 426.3 at 30.5 °C and 584.7 at 20 °C. The mealybug population reached 50% mortality after 37.5, 21.5, 19.0 and 19.0 days respectively at 20, 23.5, 27 and 30.5 °C. The results indicate that *P. manihoti* can persist and increase in numbers within the range between 20 and 30.5 °C.

Introduction

The cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr., is presently one of the worst agricultural pests in Africa. It attacks cassava (*Manihot esculenta* Crantz), a major staple food, causing yield losses of 54-84% for roots (Nwanze, 1982) and 100% for leaves which are eaten as vegetable in many countries in Africa.

A biological control programme is being developed at this Institute in order to contain this pest, introduced into Africa from Latin America. For the success of this programme, it is essential to know in detail the biology and reproductive capacity of *P. manihoti*. This information can be obtained by constructing life tables over the complete range of tolerable temperatures. The life table technique provides development, survivorship and fecundity data which are then used to calculate the intrinsic rate of natural increase and other related rates of population change. These rates can be used to better understand population changes of the pest in the field, which may be necessary for a timely release of mass produced natural enemies.

Nwanze (1978) and Fabres & Boussiengue (1981) reported on some aspects of the biology, and Iheagwam (1981) assessed population increase rates of *P. manihoti* at 25, 28 and 31 °C but in the field the pest is exposed to temperatures as low as 20 °C.

An experiment was conducted to determine the effect of a wider range of constant temperatures on the development, adult longevity, fecundity and rates of population change of the cassava mealybug. The results are reported in this paper.

Materials and methods

Four potted cassava plants (variety TMS 30001) aged 3 weeks were placed in each of Conviron E15 growth chambers set respectively at 20, 23.5, 27 and 30.5 °C (±1 °C) with a 12 h photophase. Throughout the experimental period the relative humidity (x ± SD) in these chambers was 83.7 ± 4.8, 83.3 ± 4.7, 71.8 ± 6.4 and 97.8 ± 5.2% respectively. The plants were then infested with unfed crawlers.

by placing one crawler on each leaf. After 24 h five to seven crawlers were kept on each plant. They were observed daily until they reached adulthood. After oviposition started each female was checked every 24 h until it died to record the adult longevity and to remove the eggs (the species is thelytokous). The eggs were placed in small vials using a fine camel hair brush and counted under a binocular microscope; egg counting was expedited by dissolving the eggsacks in 70% alcohol. Mortality of immature stages was negligible and, therefore, was not assessed.

Longevity and daily fecundity data were used with the developmental period to construct the age-specific survival and fecundity tables and to calculate the following parameters (Birch, 1953; Andrevartha & Birch, 1954; Southwood, 1975):

a) \( x \): age of individuals in days;

b) \( I_x \): age-specific survival; proportion of individuals still alive at age \( x \);

c) \( m_x \): age-specific fecundity: female offspring per female (only female offspring are produced by \( P. \) manihoti);

d) GRR: gross reproductive rate: female eggs per female without considering survivorship;

e) \( R_0 \): net reproductive rate: no. female progeny per female per generation

\[
R_0 = \sum I_x m_x
\]

f) \( r_m \): intrinsic rate of natural increase; calculated from the formula

\[
\Sigma I_x m_x e^{-r_m x} = 1
\]

where \( e \) is the base of natural logarithms;

g) \( T \): generation time: mean length of a generation from the birth of parents to that of offspring:

\[
T = \frac{\log R_0}{r_m}
\]

h) \( \lambda \): finite rate of increase; multiplication per female per unit time

\[
\lambda = e^{r_m}
\]

Results and discussion

Table 1 shows the influence of temperature on demographic parameters of the cassava mealybug. There was an inverse relationship between adult longevity and temperature. The adult longevity was longest (38.3 days) at 20°C and decreased sharply as the temperature increased. Survivorship curves are shown in Figure 1. All resemble Pearl's type I curve (Krebs, 1978) at each experimental temperature; very little mortality at younger age but the mortality rate increases as mealybugs get old. The time required for the population to reach 50% mortality (LT50), which also expresses the effect of temperature on longevity, was estimated from survivorship curves. This parameter also decreased at the higher temperatures.

These results are in line with those reported by Iheagwam (1981). The inverse relationship observed between adult longevity and temperature has been reported for other insects (Clark & Rockstein, 1964; Cardona & Oatman, 1975).

At all temperatures the daily mean fecundity (\( m_x \)) was highest on the first or second day of oviposition and declined thereafter (Fig. 1). The mean total fecundity was highest (584.6 eggs/♀) at 20°C and lowest (425.3 eggs/♀) at 30.5°C. The oviposition period was greatly affected by the temperature. It was longest (37.3 days) at 20°C and shortest (17.0 days) at 30.5°C (Table 1). Nwanze (1978) reported an average fecundity of 440.9 eggs at a mean room temperature of 27°C which agrees with 443.4 eggs recorded at 27°C in this study. Iheagwam (1981) also observed that the average fecundity decreased as temperature increased in the range between 25 and 31°C but reported generally a lower fecundity than that found in this experiment.

The values of the different rates of population change are shown in Table 1. The gross reproductive rate reached a peak (695 eggs/♀) at 23.5°C whereas the net reproductive rate reached its peak (585 eggs) at 20°C. The mean generation time was also inversely related with temperature but was longer at 30.5°C than at 27°C. The intrinsic rate of natural increase (\( r_m \)) was lower at 20°C than at higher temperature. The values of the weekly finite rate of increase (\( \lambda \)) increase from 2.2 at 20°C to 3.6 at 27°C before decreasing to 3.4 at 30.5°C (Table 1). The influence of temperature on population can also be visualized by the values of the doubling
Fig. 1. Effect of temperature on age-specific fecundity (---) and adult survival (O---O) rates of *P. manihoti*.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>20</th>
<th>23.5</th>
<th>27</th>
<th>30.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development time (days)</td>
<td>45.9 ± 0.4</td>
<td>36.2 ± 6.5</td>
<td>27.3 ± 0.3</td>
<td>28.7 ± 0.4</td>
</tr>
<tr>
<td>Mean adult longevity</td>
<td>38.4 ± 1.8</td>
<td>22.8 ± 1.3</td>
<td>19.9 ± 0.9</td>
<td>18.3 ± 0.8</td>
</tr>
<tr>
<td>Mean oviposition period (days)</td>
<td>37.5</td>
<td>21.5</td>
<td>19.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Mean fecundity (eggs/♀)</td>
<td>584.6 ± 29.4</td>
<td>571.5 ± 42.3</td>
<td>443.4 ± 22.0</td>
<td>425.3 ± 25.9</td>
</tr>
<tr>
<td>LT50 (days)</td>
<td>37.3 ± 1.8</td>
<td>21.4 ± 1.3</td>
<td>18.6 ± 0.8</td>
<td>17.0 ± 0.8</td>
</tr>
<tr>
<td>GR</td>
<td>656.2</td>
<td>695.0</td>
<td>482.8</td>
<td>459.0</td>
</tr>
<tr>
<td><em>R₀</em></td>
<td>584.6</td>
<td>573.4</td>
<td>443.2</td>
<td>426.3</td>
</tr>
<tr>
<td><em>r m</em></td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td><em>T</em></td>
<td>55.9</td>
<td>37.6</td>
<td>32.9</td>
<td>34.2</td>
</tr>
<tr>
<td><em>λ</em> (per week)</td>
<td>2.2</td>
<td>3.3</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Doubling time (days)</td>
<td>6.1</td>
<td>4.1</td>
<td>3.7</td>
<td>3.8</td>
</tr>
</tbody>
</table>

* Symbols are explained in text.
time which is the time required for a population to double its size. Table 1 contains the values of the parameter. *P. manihoti* has the capacity to double its population size in 6.1 days at 20 °C whereas only 3.8 days are required at 30.5 °C. The values of \( r_m \), \( T \), \( \lambda \), and doubling time agree with those reported by Iheagwam (1981).

The results indicated that *P. manihoti* can persist and increase in numbers between 20 and 30.5 °C since the value of \( r_m \) in this range was greater than zero. However, the increase in the development time and in the value of \( T \) at 30.5 °C may indicate that this temperature is close to the upper thermal threshold for development of the mealybug. The value of the net reproductive rate was high. These high growth rates may explain the observed capacity of *P. manihoti* rapidly to build up its populations in the field, from very low levels during the rainy season, to explosive levels during the favorable conditions of the dry season (Lema, unpublished). The cassava mealybug is very scarce during the rainy season and the great majority of individuals are crawlers protected inside the leaf buds and bunched shoots produced by the plants as a reaction to the insect's toxin introduced during feeding (Lema, unpublished).

The parasitoid species which is now being tested at IITA, *Epidinocarsis lopezi* (De Santis), attacks mostly the second instar and early third instar mealybug. Eggs and crawlers are not parasitized and most attacks on late third instars and fourth instars are not successful as these stages flap the posterior end of the body when disturbed by the parasitoids (Lema, unpublished).

To reduce the mealybug's rapid population increase mass produced parasitoids (Lema & Herren 1985) must be released in large enough numbers by the onset of the dry season. For some countries like Nigeria, where a dry spell is experienced before the dry season, some releases can also be made during this spell.

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**Résumé**

Influence de températures constantes sur les taux de croissance de populations de la cochenille du manioc *Phenacoccus manihoti*


Le taux intrinsèque d'accroissement naturel \( r_m \) a augmenté de 0.114 à 20 °C, à 0.185 à 27 °C, avant de descendre à 0.182 à 30.5 °C. Le taux net de reproduction \( R_o \) a été relativement élevé (426–584 œufs femelles/génération). Dans nos conditions expérimentales, la mortalité a atteint 50% au bout de 37.5, 21.5, 19.0 jours respectivement à 20, 23.5, 27 et 30.5 °C. La durée du cycle et le coefficient d'accroissement \( \lambda \) étaient inversement liés à la température. Le ravageur possède la capacité de doubler sa population en 6.08 jours à 20 °C alors que 3.81 jours seulement suffisent pour doubler la population à 30.5 °C.

Ces résultats nous ont permis de comprendre et d'expliquer l'enorme pouvoir de pullulation de la cochenille observée dans les champs pendant la saison sèche; il s'ensuit que les lâchers des entomophages produits en élevages doivent se faire très tôt au début de la saison sèche, afin de contrer la grande fertilité et la capacité d'augmentation rapide des populations de *P. manihoti*.

**References**


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