Rearing and breeding of the Moroccan locust *Dociostaurus maroccanus* (Thunberg) (Orthop., Acrididae) under laboratory conditions

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**Abstract:** The objective of the present work was to design a rearing method for the Moroccan or Mediterranean locust *Dociostaurus maroccanus* and to breed it. The duration of the post-embryonic development from N1 to adult ranged between 35 and 38 days, independently of whether nymphs were reared at constant temperature or in cages with incandescent light bulbs that afford heat for thermo-regulation. In contrast, the number of nymphs reaching the adult stage was directly related to the power of the bulb from 0 to 60 W. The rearing density did not affect the survival and developmental time of nymphs over the range 100–400 nymphs per cage. The survival of *D. maroccanus* nymphs under optimal conditions, which were a 60 W bulb and 400 nymphs per cage, was around 60%. The mean number of egg-pods per female ranged between 2.6 and 3.5, and no difference was observed among rearing densities, with 16 pairs per cage being the optimal breeding condition. The number of eggs per egg pod ranged from 15 to 25, the egg viability from 20 to 50% and the adult longevity from 30 to 40 days. Eggs deposited by *D. maroccanus* females reared under these laboratory conditions were viable and thus the present study has ‘closed’ the life cycle of this species for the first time. The rearing method developed in this study will provide elements for studies of biology and physiology and it can be used in the design of new, environmentally sound pest management measures.

1 Introduction

Progress in entomological research and success of pest management programmes depend on our ability to rear insects and establish colonies in the laboratory (Singh and Moore, 1985). *Dociostaurus maroccanus* is an important plague locust of the Mediterranean region that has been frequently investigated (Uvarov, 1928; Casíz and Moreno-Marquez, 1950; Merton, 1959; Latchinsky and Launoux-Luong, 1992). Nevertheless, a rearing method for this species has not been developed, probably due to its extremely long embryonic development that extends for more than 9 months (Bodenheimer and Shulov, 1951); thus post-embryonic stages are available only during 3 months per year when they can be found in natural conditions.

Recent studies have pointed out that the two arrests of the embryonic development of this species (Bodenheimer and Shulov, 1951) can be overcome by laboratory manipulation (Quesada-Moraga and Santiago-Alvarez, 1999, 2000). Furthermore, the diapause can be overcome by a period of cold exposure to around 10°C and the total embryonic development shortened to 80–90 days (Quesada-Moraga and Santiago-Alvarez, 1999, 2000). The effective management of the embryonic development aims at establishing a stock colony in the laboratory that will provide elements for studies about biology, physiology and pest control measures. In this article we present a method for rearing *D. maroccanus* under laboratory conditions and a breeding method.

2 Materials and methods

One hundred egg-pods were collected from a field in a permanent breeding area of la Serena (Badajoz, Spain) (38°55′N, 5°29′W) in June 1997. Egg-pods were placed at the bottom of 210 ml styrofoam cups (15 per cup) covered by 5 cm of moistened vermiculite (1.5 ml distilled water/1 g vermiculite). They were incubated at 25°C for about 40 days to complete anatrepsis (diapause stage), then at 10°C for 30–40 days to accelerate diapause development and termination and finally at 25°C for 15–20 days until hatching (Quesada-Moraga and Santiago-Alvarez, 1999).

Rearing of the locusts was carried out in an insectary regulated at 26°C, 60% relative humidity, under a 13 h light : 11 h dark photoperiod. Two sizes of rearing cages made of wooden frames and metallic mesh were used: 50 cm × 50 cm × 50 cm for nymphs and 30 cm × 30 cm × 30 cm for adults. nymphs were allowed to move vertically in a heat gradient provided by 40 W or 60 W incandescent light bulbs that were mounted in the middle of the upper wall of the cages. A metallic mesh tube (8 cm diameter × 45 or 27 cm high in nymphs and adult cages, respectively) was placed under the bulb to permit the vertical movement of nymphs. The temperature regime for each combination of cage size and bulb power is presented in table 1. An additional experiment of rearing at constant temperature
was made for comparison. The locusts were fed with dry wheat bran, wheat seedlings and cabbage.

At hatching, nymphs were placed in cages for monitoring and recording survival percentage and instar duration. The duration of each instar was monitored from the time at which 50% of the nymphs reached a particular instar until 50% of the nymphs reached the following instar.

Newly emerged adults were transferred from 50 cm × 50 cm × 50 cm cages to the smaller 30 cm × 30 cm × 30 cm ones. Plastic containers (800 ml) filled with sterile wet sand were placed at the bottom of the adult cages for oviposition. Egg-pods were removed every day and kept in 210 ml styrofoam cups covered by wet vermiculite. Groups of three styrofoam cups were placed in self-sealing plastic bags and incubated as previously described until hatching. Longevity, first copulation, pre-oviposition period and egg production were monitored for the full life of the adults. Statistical analysis of data was carried out using the program Statistic 4.1 for Windows.

### 3 Results

The duration of the post-embryonic development of *D. maroccanus*, ranged between 36 and 38 days, and was independent of whether the nymphs were reared at constant temperature or in cages that afford heat for thermo-regulation (table 2). In contrast, the number of nymphs reaching the adult stage was directly related to the power of the bulb, increasing from 10.8% at constant temperature to 25.3% in cages with 40 W bulbs, and to 64.6% in cages with 60 W bulbs (table 2). On the other hand, the effect of rearing density on survival and development time of nymphs was tested in cages with 60 W bulbs (table 3). It was clearly observed that these two parameters did not differ between cages with 100 nymphs and those with 400 nymphs, the survival of nymphs was 60% and the development time 35 days (table 3).

Neither the rearing density nor the bulb power affected the duration of each instar. The second instar was the shortest (4–6 days) and the fifth instar the longest (9–12 days). The first and fourth instars were synchronous (6–8 days) and shorter than the third one (7–9 days).

Sixty-two newly moulted adults, males and females, coming from nymphs reared in cages with 60 W bulbs, were removed to adult cages with 60 W bulbs in graded numbers of pairs from 1 to 16 (table 4). Independently of the number of pairs in the cages, the first copulation occurred 5 days after the imaginal moult and the pre-oviposition period extended to 10 days. The mean number of egg-pods per female ranged between 2.6 and 3.5, and no difference was observed among rearing densities (table 4).

Pods deposited by females in cages with one and two pairs were damaged during the counting of eggs, but the pods from cages with four, eight and 16 pairs were manipulated in order to force embryonic development for studying the viability of eggs. Egg viability was near 50% in two cages and 20% in the other (table 4). Adult longevity, ranged from 30 to 40 days and was independent of the number of pairs in the cage (table 4). Similar longevity values were observed when the adults from nymphs reared in cages with 40 W bulbs were transferred to adult cages with 40 or 60 W bulbs, and when the adults from nymphs reared in cages with 60 W bulbs were transferred to adult cages with 40 W bulbs. In contrast, the adults from nymphs reared in cages without bulbs and transferred to cages at constant temperature had a maximum longevity of 7 days.

A new experiment was designed in order to provide a more detailed analysis of the influence of the heat source within the cages on the efficacy of the rearing

### Table 1. Temperatures (°C) on and within cages with varying light bulb powers. Temperatures were recorded with a copper constantan thermocouple (0.127 mm diameter)

<table>
<thead>
<tr>
<th>Cage size</th>
<th>Location</th>
<th>Light bulb power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>40 W</td>
</tr>
<tr>
<td>50 cm × 50 cm × 50 cm</td>
<td>Base of the cage</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Lower surface of the bulb</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Maximum on side of cage</td>
<td>31</td>
</tr>
<tr>
<td>30 cm × 30 cm × 30 cm</td>
<td>Base of the cage</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Lower surface of the bulb</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Maximum on side of cage</td>
<td>33</td>
</tr>
</tbody>
</table>

### Table 2. Survival (% of nymphs reaching the adult stage) and development time (number of days from star of first instar to imaginal moult) for *D. maroccanus* nymphs reared under different densities and temperature gradients

<table>
<thead>
<tr>
<th>N</th>
<th>C</th>
<th>Wp</th>
<th>%</th>
<th>Development time</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>4</td>
<td>off</td>
<td>32.3 ± 11.7</td>
<td>10.8 ± 3.9</td>
</tr>
<tr>
<td>300</td>
<td>1</td>
<td>40</td>
<td>76</td>
<td>25.3</td>
</tr>
<tr>
<td>300</td>
<td>1</td>
<td>60</td>
<td>194</td>
<td>64.6</td>
</tr>
</tbody>
</table>

C, number of cages; Wp, bulb power in Watts; n, number of insects.

### Table 3. Survival (% of nymphs reaching the adult stage) and development time (number of days from star of first instar to imaginal moult) for *D. maroccanus* nymphs reared under different densities in cages with 60 W bulbs

<table>
<thead>
<tr>
<th>N</th>
<th>C</th>
<th>%</th>
<th>Development time</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2</td>
<td>57.0 ± 1.4</td>
<td>35.5 ± 0.7</td>
</tr>
<tr>
<td>400</td>
<td>2</td>
<td>235.5 ± 37.4</td>
<td>34.5 ± 2.1</td>
</tr>
</tbody>
</table>

C, number of cages; n, number of insects.
method. Mortality data was recorded daily from six cages, each containing around 100 nymphs collected from a field. Two cages remained at constant temperature for the full experiment, four cages had 60 W bulbs during the light period, with the bulbs of two of these cages switched off 15 days after the beginning of experiment (fig.). The survival rate of nymphs reared at constant temperature decreased quickly towards a minimum that was reached after 20 days. In contrast, the survival rate of nymphs reared in cages with 60 W bulbs decreased slightly towards a minimum that was reached after 40 days. When the bulb was switched off 15 days after the beginning of the experiment, the survival ratio suffered a sharp decline (fig.).

### 4 Discussion

This is the first record on the breeding of *D. marocc- anus* under laboratory conditions. In a previous attempt, the species was maintained under laboratory conditions but the full life cycle of the species was not closed (GRADOJEVIC, 1960).

Our results clearly show that the presence of an extra heat source within the cages, the bulb, for thermo-regulation is indispensable to the rearing of *D. marocc- anus*. Therefore, the rearing of this locust at constant temperature is not viable. Although 40 W bulbs have lower electric consumption than 60 W bulbs, their use leads to a reduction in survival and so they should not be used. This decrease in the survival is probably due to the reduction of the power of the heat source that does not allow locusts to thermo-regulate under optimal conditions (CASEY, 1988).

The total duration of *D. maroccanus* development until the adult stage is similar to those of *Taeniopoda eques* (Burmeister) (Orthop., Acrididae) and *Schistocerca gregaria* (Forskål) (Orthop., Acrididae) (SINGH and MOORE, 1985; WHITMAN, 1986) but it is around 10 days shorter than that of *Melanoplus sanguinipes* (F) (Orthop., Acrididae) (SINGH and MOORE, 1985). The full life cycle of this species can be achieved in around 120–130 days, considering the duration of the post-embryonic development, the pre-oviposition period and the embryonic development (QUESADA-MORAGA and SANTIAGO-ÁLVAREZ, 1999, 2000). The adult longevity permits an additional period of 20 days to get a higher number of egg pods for the following generation. It is possible consequently to get at least two generations per year in the laboratory. Nevertheless, the management of the embryonic development can allow an overlapping of egg hatching, and hence a continuous supply of post-embryonic stages.

Variations in the rate of development were not recorded at different rearing densities. We selected a maximum density of 400 nymphs per cage because a higher number resulted in too many problems for the daily manipulation schedule, and a minimum of 100 nymphs because a lower number was considered as a waste of volume within the cage, diet materials and energy. Under our particular conditions, the optimum rearing condition would be 400 insects per cage because it offers greater colonies without negative interference in the survival of the nymphs due to competition for food or heat. It would probably be necessary to consider higher differences between rearing densities to detect any differences in the rate of development as observed in other locust (NORRIS, 1950, 1952; GILLETT, 1975; NOLTE, 1976).

The survival of *D. maroccanus* nymphs under optimal conditions was higher than 50% as frequently observed in other locusts rearing (SINGH and MOORE, 1985; SCHMIDT and ALBERTZ, 1994; HARTFORD ET AL., 1995). Therefore, our rearing method seems to be adequate for this locust, although an improvement in the method could be achieved by changing wheat seedlings for annual graminea from *D. maroccanus* breeding areas.

The different numbers of adult pairs were selected in order to optimize equipment, diet materials and energy. We did not select more than 16 pairs per cage due to manipulation difficulties in the daily schedule. The results show that the optimum number of pairs in the cages is 16 because it allows an increase in the availability of egg-pods for the next generation without

<table>
<thead>
<tr>
<th>N</th>
<th>Males</th>
<th>Females</th>
<th>Egg-pods/ female</th>
<th>Eggs/pod</th>
<th>Egg hatchability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32.5 ± 0.7 a</td>
<td>34.0 ± 0.0 a</td>
<td>3.5 ± 0.7</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>35.0 ± 2.3 a</td>
<td>35.3 ± 26.7 a</td>
<td>2.8 ± 0.3</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>40.7 ± 16.3 a</td>
<td>37.5 ± 10.0 a</td>
<td>3.0 ± 0.7</td>
<td>22.5 ± 6.4</td>
<td>43.4 ± 6.5</td>
</tr>
<tr>
<td>8</td>
<td>29.3 ± 11.4 b</td>
<td>38.9 ± 10.9 a</td>
<td>2.6 ± 0.8</td>
<td>16.7 ± 8.6</td>
<td>17.1 ± 7.0</td>
</tr>
<tr>
<td>16</td>
<td>36.0 ± 11.6 a</td>
<td>39.1 ± 9.3 a</td>
<td>2.6 ± 0.1</td>
<td>16.7 ± 6.1</td>
<td>46.3 ± 32.5</td>
</tr>
</tbody>
</table>

Data are mean ± standard deviation, means within columns with the same letter are not significantly different (least significant difference (LSD) at the 5% level).

**Table 4. Longevity and reproductive parameters of *D. maroccanus* reared in the laboratory under different number of pairs (N)**

![Survival rate of *D. maroccanus* fifth instar nymphs under different conditions for thermo-regulation](image-url)
causing any negative effects in all the life cycle parameters of the adults. The longevity of *D. marocc-anus* adults reared under laboratory conditions is similar to that of *Locusta migratoria* (L) (Orthop., Acrididae) (Norris, 1950) but 20 days shorter than those of *Aiolopus thalassinus* (Fabr.) (Orthop., Acrididae) (Schmidt and Othman, 1994) and *S. gregaria* (Schmidt and Albütz, 1994). The number of egg-pods deposited by *D. maroccanus* females reared under optimal conditions was higher than that observed under natural conditions where no more than two egg-pods are normally deposited (Merton, 1959; Latchinsky and Launois-Luong, 1992; Quesada-Moraga, 1998). This increase of number of egg-pods under laboratory conditions is a common feature as has been clearly established (Uvarov, 1966). The present results indicate that eggs deposited by *D. maroccanus* females reared under laboratory conditions are viable and this study has ‘closed’ the life cycle of this species for the first time.

The rearing method developed in this study can lead to greater progress in the study of the Mediterranean or Moroccan locust and to the design new environmentally sound pest management measures.

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