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Technical Note

Thermal requirements of *Ophyra albuquerquei* Lopes, 1985 (Diptera, Muscidae)

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ABSTRACT

This study determines the development rates of the immature stages of the fly *Ophyra albuquerquei* Lopes, 1985. In this study, with 70% relative humidity and a 12-h photophase, eggs, larvae, and pupae were kept in a biochemical oxygen demand chamber at temperatures of 10, 15, 17, 20, 22, 25, 27, 30, 33, 35, and 40 °C. While the rearing temperature increases, the development time for each immature stage of *O. albuquerquei* decreases and these stages develop at temperatures from 10 to 35 °C. For eggs, the average minimum development time was 16 h, and the average maximum development time was 81 h. The average minimum development time for larvae and pupae was 7 and 6 days, respectively, and the average maximum development time was 22 and 42 days, respectively. To understand the development rate of each immature stage of the fly, a mathematical model is presented.

1. Introduction

The genus *Ophyra* Robineau-Desvoidy, 1830 contains approximately 20 species, of which seven occur in the Neotropical region: *O. cubana* Gregor, 1974; *O. aenescens* (Wiedemann, 1830); *O. albuquerquei* Lopes, 1985; *O. capensis* (Wiedemann, 1818); *O. ignava* (Harris, 1780); *O. calchogaster* (Wiedemann, 1824); and *O. solitaria* Albuquerque, 1958 [1].

The species of this genus are frequently associated with decaying animal matter, especially carcasses; their larvae can therefore be used in forensic entomology to determine the post-mortem interval (PMI) [2–5].

O. albuquerquei is distributed across the southeast Atlantic coast of southern Brazil and in Argentina from the Salta to Buenos Aires provinces [6,7]. The species is generally associated with wild environments where temperatures are milder for the most part of the year [8]. In southern Brazil, the species is collected most frequently during months when the average temperatures are between 15.5 and 17.4 °C; the population peaks during autumn [9].

As in many other insects, temperature is the abiotic factor that largely influences the biological aspects of *Ophyra*, altering the development and viability of immature individuals [10,11]. However, the effects of temperature on *O. albuquerquei* remain unknown.

To estimate the PMI, the important components are the thresholds for maximum and minimum temperatures. In addition, the number of generations for a species in a particular region may be estimated by considering the base temperature (Bt) values and accumulated degree-days.

Considering these factors, the aim of this study was to estimate the thermal requirements of the immature stages of *O. albuquerquei.*

2. Materials and methods

2.1. Collection and maintenance of Ophyra albuquerquei

In November 2010, adults of *O. albuquerquei* were collected around a lizard carcass on the campus of the Universidade Federal de Pelotas (UFPEL) (31°48′34″S, 52°25′42″O). A colony was established in the Laboratório de Biologia de Insetos of the Instituto de Biologia in an acclimatized room with a temperature of 25 ± 2 °C, relative humidity of approximately 80%, and 12-h photophase. The adults were maintained in 30 cm × 30 cm × 30 cm cm cages and fed with a diet made up of one part meat meal and two parts sugar; water was supplied ad libitum.

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To obtain eggs, plates containing a culture medium (two parts meat meal, one part sawdust and water) were placed inside the cages. The eggs were transferred to containers with the same diet and placed inside larvae-rearing funnels (20 cm × 20 cm). Larvae were fed until they reached the third instar stage, they left the funnel and fell into another container of moist sawdust. To replenish the cages, the fed larvae [12] were transferred to glass containers (10-cm diameter × 20-cm height) with moist sawdust and kept until adult emergence.

2.2. Estimation of the thermal requirements of the immature stages of O. albuquerquei

To evaluate the effect of different temperatures on the development period of immature *O. albuquerquei*, eggs, larvae, and pupae of *O. albuquerquei* were kept in a biochemical oxygen demand chamber at temperatures of 10, 15, 17, 20, 22, 25, 27, 30, 33, 35, and 40 °C (±0.2 °C) and a relative humidity of 70%. For each temperature, 30 individuals of each stage were kept in 10 repetitions to estimate the period of development.

Eggs were collected using an oviposition substrate consisting of the same culture medium used for colony maintenance and placed in an adult cage for 2 h. After the first 12 h, the eggs were placed in petri dishes (8-cm ⌀) with moist filter paper and observed every hour to determine the development period. The larvae were kept in small containers (8-cm diameter × 10-cm height) covered with organza containing 300 g of the same culture medium used for colony maintenance.

Post-feeding third instar larvae were collected after each larva left the culture medium and were individualized in test tubes containing moist sawdust and covered with plastic film. Larvae and pupae were observed at 24-h intervals. The larvae reached the pupal stage when each larva left the medium until the emergence of adults.

2.3. Estimation of the base temperature, accumulated degree-hour, and accumulated degree-days of the immature stages of Ophyra albuquerquei

Based on the duration of each stage of the development cycle under the tested temperatures, the Bt and thermal constants (*K*) were calculated by linear regression.

To calculate the accumulated degree-days (ADD) and accumulated degree-hours (ADH), the following equations were used:

$$\text{Expected ADH} = (\text{rearing temperature} - \text{Bt}) \times \text{development period}$$

$$\text{Expected ADD} = \frac{\text{Expected ADH}}{24}$$

2.4. Statistical analysis

The influence of temperature on the development rates of eggs, larvae, and pupae was evaluated by linear regression with the *F* distribution. All tests established significance at a probability value ≤5%. All analyses were performed using the statistical software R [13] following the methods of Crawley [14].

3. Results

Overall, while rearing temperature increases, the development time for each immature stage of *O. albuquerquei* decreases. The average periods of development for the eggs, larvae, and pupae of *O. alburquequei* are presented in Tables 1–3, respectively.

Table 1
Average period of development ± standard deviation in hours (H), development rate (1/H), and the minimum–maximum individual development period (mmdp) of the egg stage of *Ophyra albuquerquei* Lopes, 1985, as a function of temperature under controlled conditions.

Temperature (°C)	H	1/H	mmdp
10	–	–	–
15	81 ± 2.63	0.01	77–101
17	52 ± 13.40	0.01	40–67
20	46 ± 2.38	0.02	43–54
22	33 ± 6.41	0.03	28–59
25	28 ± 18.44	0.03	22–29
27	24 ± 0.93	0.04	23–26
30	22 ± 0.76	0.04	22–34
33	20 ± 0.84	0.05	20–21
35	16 ± 1.78	0.06	15–24
40	–	–	–

Embryo development during the egg stage occurred between temperatures of 15 and 35 °C, with the average development period ranging from 16 to 81 h (Table 1). The embryo development rate accelerated as the temperature increased ($F_{1,88} = 1179.4$; $P < 0.001$; Fig. 1A).

Larvae developed at temperatures between 15 and 40 °C. The larval period decreased with increasing temperature (Table 2), varying from 7 to 22 days. Higher temperatures led to more rapid larval development rates ($F_{1,86} = 179.19$; $P < 0.001$; Fig. 1B).

The pupae developed at temperatures between 10 and 35 °C (Table 3), with the average development period ranging from 8 to 43 days. The temperature had a direct and proportionate influence on the development rate of pupae ($F_{1,85} = 649.62$; $P < 0.001$; Fig. 1C).

Along with the mathematical model for the rate of development for each stage, the values of the lower Bt, *K*, and determination coefficients for the eggs, larvae, and pupae of *O. albuquerquei* are presented in Table 4.

4. Discussion

Although several species of *Ophyra* have been extensively studied, few studies have been conducted regarding *O. albuquerquei*. For example, the biology of the cosmopolitan species *O. aenescens* is very well documented, with many papers examining the influence of temperature on its development and the possibility of applying the species as a biological control agent

Table 2
Average period of development ± standard deviation in days (D), development rate (1/D), and the minimum–maximum individual development period (mmdp) of the larval stage of *Ophyra albuquerquei* Lopes, 1985, as a function of temperature under controlled conditions.

Temperature (°C)	D	1/D	mmdp
10	–	–	–
15	18 ± 3.82	0.05	13–26
17	22 ± 14.28	0.04	12–22
20	13 ± 3.29	0.07	10–32
22	15 ± 2.48	0.06	12–22
25	14 ± 2.96	0.07	8–19
27	13 ± 5.88	0.07	8–24
30	9 ± 2.17	0.11	6–13
33	7 ± 1.25	0.14	6–9
35	7 ± 2.51	0.12	4–15
40	8 ± 2.61	–	6–15