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The Influence of Low Temperature on Development, Adult Longevity and Productivity of *Zaprionus indiana* Gupta (Diptera : Drosophilidae)

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Abstract. Development, adult longevity and productivity of *Zaprionus indiana* was studied in relation to constant low temperature in the laboratory. The data were used to develop a degree-day (DD) model for predicting population events in the field. An estimated 227.3 DD for male and 208.3 DD for female (10.07 and 10.13°C lower threshold for male and female) were required for development from egg to adult. Mean adult longevity ranged from 80.9 days for males and 88.9 days for females at 15.0°C to 46.6 days for males and 52.9 days for females at 22.5°C. A higher egg mortality was observed at all the 4 constant temperatures tested than in the other stages. Females produced 218 eggs at 20.0°C and 395 eggs at 22.5°C. At 20.0 and 22.5°C, about 87.4 and 88.8% of the total number of eggs were produced during the initial 45 days of oviposition period, respectively.

Introduction

Up to 1970 the Drosophilid fly *Zaprionus indiana* Gupta 1970, was known only from India and Pakistan [1-2]. Recently, the fly was recorded at Taif area, Western Province, Saudi Arabia [3]. Although, the biology and economic importance of some drosophilid flies have been well documented [4 to 11], little is known regarding the basic biology of *Z. indiana.*

Temperature is the most important factor affecting poikilotherms [12]. The temperature-dependent developmental rate curve of an insect is a fundamental feature of its life cycle. The curve may be modified by humidity, nutrition, etc., but temperature remains the dominant driving force [13]. This response to temperature can affect the geographical distribution and seasonal abundance of the species.

In the present study the influence of 4 constant temperatures on developmental rate, adult longevity and productivity of *Z. indiana* was investigated. Humidity, photoperiod and food were held constant. The study will help to determine the possibility that the fly can invade other territories in the Kingdom.

Materials and Methods

A laboratory culture of *Z. indiana* was established in November 1988 from field collected larvae from infested pomegranate fruit *Punica granatum* L., at Taif area, Western Province, Saudi Arabia. The culture was maintained in the laboratory on 4-24 Instant *Drosophila* medium (Carolina Biological Supply Company, U.S.A.) at 25°C, 75°C, 75% relative humidity and under continuous light.

The developmental time intervals from oviposition to pupation and from pupation to emergence, adult longevity and productivity were evaluated at constant temperatures of 15, 17.5, 20, and 22.5°C, using the procedures described by Amoudi *et al.* [3].

The relationship between temperature and rate of development, the lower thresholds (t_L) for development and degree-days (DD) necessary for completing each stage were estimated using a 1-way linear regression analysis models ($y = a + b.x$) of developmental rate (y = 1/developmental time) as a function of constant temperature (x) [14]. The t_L (X intercept of the model) is defined as the temperature below which no measurable development occurs, and DD = reciprocal of the slope (b). Values of t were obtained by standard methods [14]. Analysis of developmental rate and adult longevity were computed using a 1-way linear regression (F test) (Minitab Inc. 1986, U.S.A.). Comparisons weights of adults at emergence, preoviposition period and productivity were computed using a 1-way analysis of variance (F test).

Mean generation life span was obtained by calculating the periods of egg incubation and larval and pupal durations plus the female preoviposition period.

Results

Development time

The development time under the constant temperature regimes is shown in Table 1.

The total development time for both sexes decreased more between 15.0 and 17.5°C, and much less between 17.5 and 20.0°C and between 20.0 and 22.5°C (Table 1). Total development time from oviposition to emergence of adult was significantly different and the response was similar in both sexes ($F = 673.88$; df = 1,2; $P \leqslant 0.01$) for male and ($F = 167.92$; df = 1,2; $P \leqslant 0.01$) for female. The duration of larvae and pupae for both sexes decreased between 15.0 and 17.5°C, while between 17.5 and

Table 1. Mean development times (days) of *Z. indiana* stages reared at constant low temperatures.

Temp. °C	Egg*			Sex	Larva			Pupa		Egg to adult	
	No.	x̄ ± SEM	(Min.-Max.)		No.	x̄ ± SEM	(Min.-Max.)	x̄ ± SEM	(Min.-Max.)	x̄ ± SEM	(Min.-Max.)
15	316	5.81±0.09	(3.0–10.0)	♂	45	24.0±0.57	(19–31)	14.6±0.12	(12–16)	44.8±0.52	(40–51)
				♀	70	21.5±0.47	(16–31)	14.3±0.11	(12–16)	41.8±0.42	(37–51)
17.5	345	4.12±0.06	(2.5– 7.0)	♂	68	15.8±0.27	(13–21)	11.2±0.18	(9–14)	30.9±0.33	(26–37)
				♀	64	14.9±0.29	(12–20)	10.7±0.12	(8–14)	29.8±0.36	(24–35)
20	393	3.10±0.04	(2.0–5.0)	♂	97	9.9±0.16	(8–15)	9.3±0.13	(6–12)	23.3±0.16	(20–27)
				♀	97	9.8±0.16	(8–14)	8.6±0.12	(6–11)	22.5±0.18	(19–27)
22.5	417	2.85±0.03	(1.5– 4.5)	♂	96	7.8±0.11	(6–10)	7.2±0.10	(6–9)	18.0±0.11	(16–20)
				♀	66	7.1±0.18	(6–10)	6.7±0.11	(6–8)	16.7±0.17	(15–21)

*Each experiment began with 500 eggs.

22.5°C the decrease was relatively slower (Table 1). The development time of males was signficantly different from that of females at all temperature regimes ($P \leq 0.05$).

Development rates and temperature threshold for each stage used to calculate DD necessary for development of the life stages are presented in Table 2, and Fig. 1. Based on a calculated threshold temperature for total development the lower thresholds were 10.07°C for male and 10.13°C for female (Table 2). Mean DD accumulations required for completion of total development were 227.27 for males and 208.33 for females (Table 2). The r^2 values indicated that the responses of *Z. indiana* life stages to constant temperature were linear and predictable with regression for both sexes; r^2 values ranged from 96.8 (egg) to 99.7 and 98.8% (oviposition to adult) for males and females, respectively.

Overall morality decreased as a function of increasing temperature (Table 3). While a higher egg morality was observed at all constant temperatures tested, there was a decreasing trend in larvae and pupae with increasing temperature up to 20.0°C. At 22.5°C there was an appreciable increase in percentage of larval and pupal mortality.

Table 2. Regression of development rate (y) on rearing temperature (x) for immature stages of *Z. indiana*.

Life stage	Sex	Regression equation	DD=(1/slope)	r^2(%)	t_L(°C)
Egg	♂ + ♀	$y = -0.1900 + 0.0246x$	40.65	96.8	7.72
Larva	♂	$y = -0.1390 + 0.0119x$	84.03	99.1	11.68
	♀	$y = -0.1500 + 0.0127x$	78.74	98.2	11.81
Pupa	♂	$y = -0.0699 + 0.0091x$	109.89	98.3	7.68
	♀	$y = -0.0879 + 0.0104x$	96.15	99.1	8.45
Oviposition to adult	♂	$y = -0.0443 + 0.0044x$	227.27	99.7	10.07
	♀	$y = -0.0486 + 0.0048x$	208.33	98.8	10.13

Table 3. Mortality of *Z. indiana* stages at constant low temperatures.

Temp. (°C)	% Mortality			
	Egg	Larva	Pupa	Total
15	36.8	15.0	29.6	63
17.5	31.0	11.0	25.8	55
20	21.4	2.0	0.0	23
22.5	16.6	8.5	4.7	28

Adult activity

Mean fly weight at emergence differed significantly as a function of temperature (Table 4) and the response was similar for males ($F = 25.58$; $df = 3{,}302$; $P \leq 0.001$) and females ($F = 15.88$; $df = 3{,}293$; $P \leq 0.001$).

Mean longevity of adult *Z. indiana* differed significantly between all temperature regimes, and the response was relatively similar for both sexes ($y = 151\text{-}4.68X$; $r^2 = 0.992$; $F = 240.591$; $df = 1{,}2$; $P \leq 0.01$) for males and ($y = 158\text{-}4.79X$) $r^2 = 0.947$; $F = 35.50$; $df = 1{,}2$; $P \leq 0.05$) for females (Table 4). Longevity of *Z. indiana* males and females at 15 = C was 1.7-fold that of males and females held at 22.5°. Cumulative percentage of adult mortality at 4 constant temperatures are represented in Fig. 2.

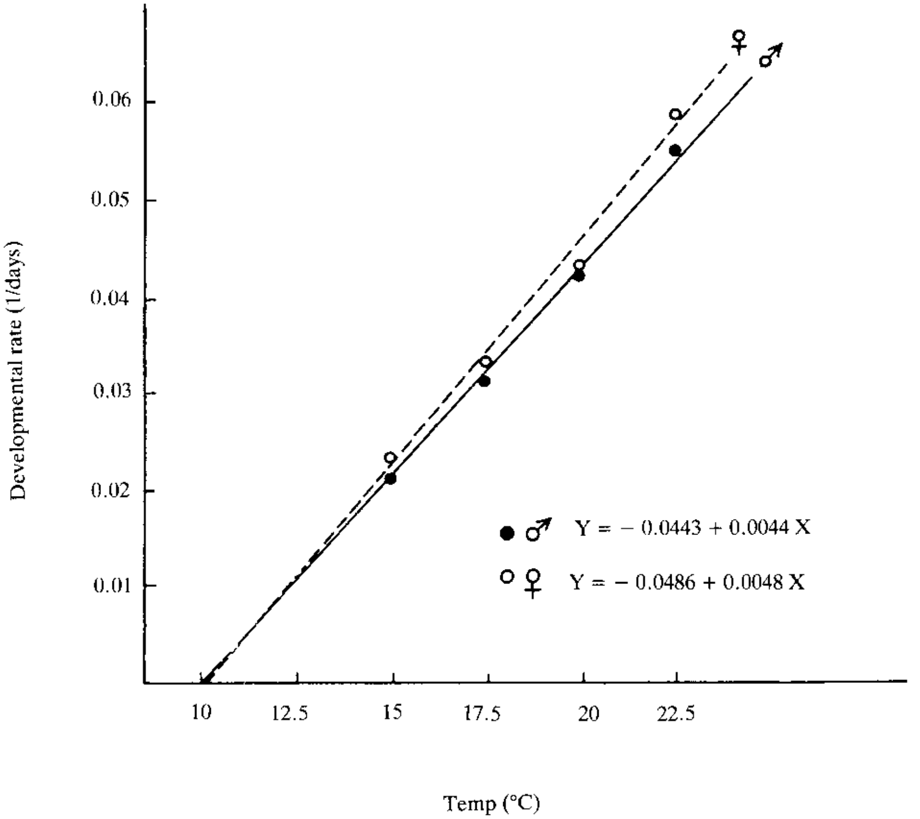

Fig. 1: Developmental rate of *Z. indiana* (oviposition to adult) reared at constant low temperatures.

Table 4. Mean adult weight at emergence, longevity, productivity and preoviposition period of *Z. indiana* reared at constant low temperatures.

Temp. (°C)	Sex	Weight per fly at emergence (mg)		Longevity (days)		Productivity/egg mean no. eggs/fly		Preoviposition period (days) η = 10
		No.	x̄ ± SEM (Min.–Max.)	No.	x̄ ± SEM (Min.–max.)	No.	x̄ ± SEM (Min.–Max.)	x̄ ± SEM (Min.–Max.)
15	♂	45	1.72±0.02 (1.5–1.9)	42	80.9±3.50 (5–120)			
	♀	70	1.67±0.02 (1.5–1.9)	42	88.9±4.11 (8–131)	42	16.0±1.63 (0–30)	27.6±1.83 (21–37)
17.5	♂	68	1.67±0.02 (1.4–1.8)	61	69.1±3.55 (5–107)			
	♀	64	1.71±0.02 (1.5–1.9)	53	70.4±3.68 (8–113)	53	90.7±7.68 (0–185)	18.7±1.76 (11–27)
20	♂	97	1.65±0.02 (1.3–1.8)	83	55.1±3.26 (4–92)			
	♀	97	1.69±0.01 (1.4–1.8)	83	58.7±3.09 (5–103)	83	218.2±8.66 (0–281)	5.8±0.25 (5–7)
22.5	♂	96	1.83±0.03 (1.6–2.1)	58	46.6±3.14 (6–85)			
	♀	66	1.84±0.03 (1.1–2.2)	55	52.9±4.04 (6–95)	55	395.8±30.36 (2–651)	4.7±0.30 (3–6)

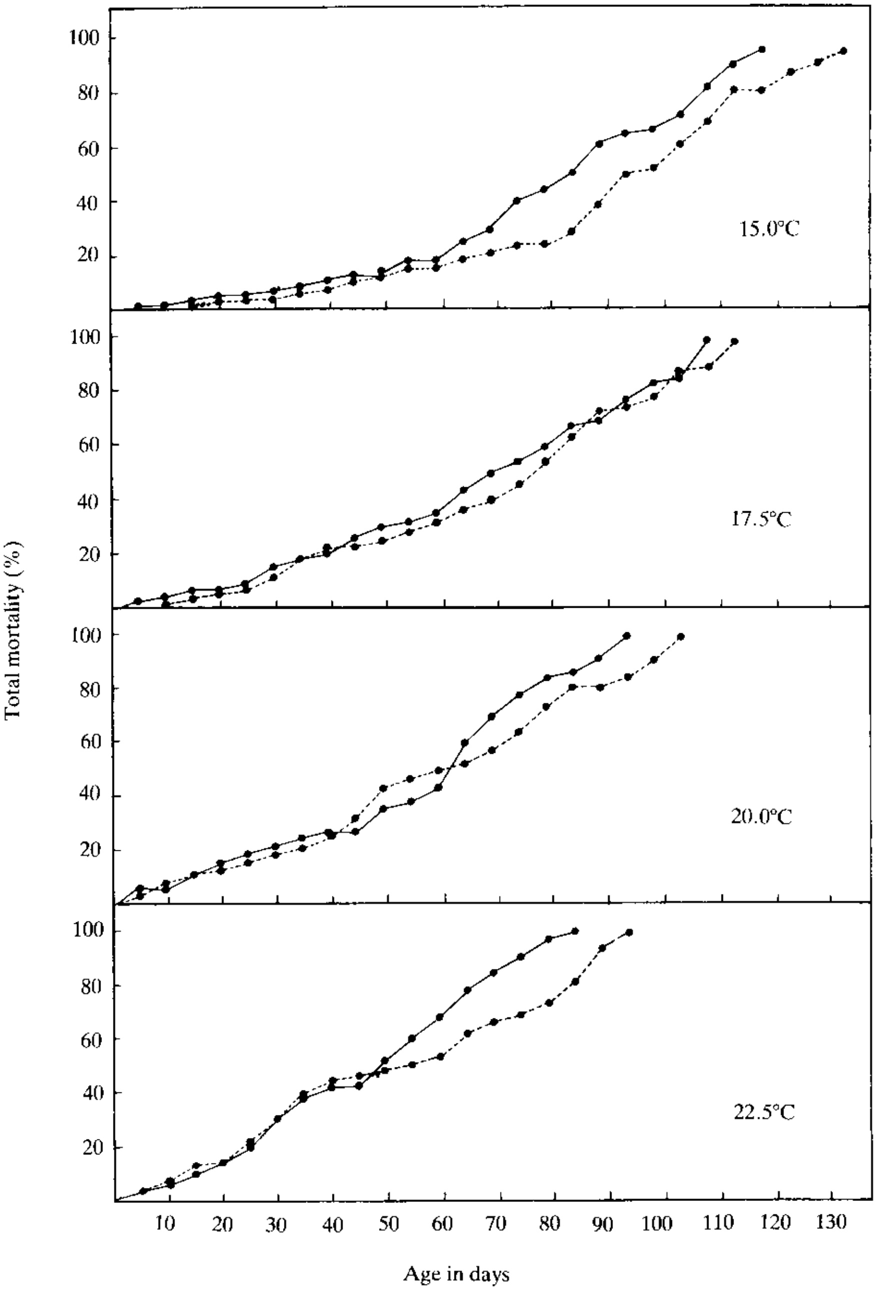

Fig. 2: Cumulative percentage of *Z. indiana* adult (males and females) mortality reared at constant low temperatures.

Mean preoviposition period was extended significantly with decreasing temperature ($F = 76.43$; $df = 3,36$; $P \leq 0.01$) Table 4). Preovipostion period of flies held at 15°C was 5.9-fold of those held at 22.5°C (Table 4).

Mean total eggs per female was significantly different between all temperature regimes ($F = 93.83$; $df = 3,229$; $P \leq 0.001$). The total number of eggs produced by female at 22.5°C was 24.7-fold that of females held at 15.0°C (Table 4). Data in Tables 1 and 4 indicates that *Z. indiana* developes well with high productivity at 20.0 and 22.5°C, with slower and less productivity at 17.5 and 15.5°C. The mean daily oviposition rate of female reared at 20.0 and 22.5°C is illustrated in Fig. 3. More that 87.4 and 88.8% of the total number of eggs was produced during the initial 45 days of oviposition period at 20.0 and 22.5°C, respectively. The average oviposition period lasted 90 days at both degrees of temperature.

Mean generation life span at 15°C (69.4 days) was much higher than that at 22.5°C (21.4 days) (Tables 1 and 4).

Discussion

The present results indicate that the development time necessary for completion of each stage of *Z. indiana* decreased with increasing temperatures. Values of lower thresholds for *Z. indiana* (t_L = 10.07°C for male and 10.13°C for females) are in the same range of those of many pests and beneficial insects [15].

The data clearly indicates that the immature stages of both sexes of *Z. indiana* have developed more readily at 20.0 and 22.5°C rather than at low temperatures. The same trend appears to apply to the adults. However, few works have been published on the response of *Z. indiana* to temperature, probably because the species has a limited range of distribution, the single report on the biology of *Z. indiana* at 22.0°C [2] supports our results. In comparison, Davidson [16] calculated 12 day-degrees for *Drosophila melanogaster* (Meigen) much lower than that reported in the present study for *Z. indiana*. The total development time recorded for *Z. indiana* was higher that that reported for both *Z, paravittiger* (Godbole and Vaidya) (18 days) [9] and *D. melanogaster* (9 days) [17] reared at 20.0°C. On the other hand, the adult longevity recorded here was similar to that reported by Sharma and Jit [9] for *Z. paravittiger* reared at comparable temperatures. In contrast, the mean life span of female *Z. indiana* at 22.5°C recorded in the present study ($16.7 + 4.7 = 21.4$ days) was similar to that reported by Shakoori and Butt [2] for the same fly at the same temperature.

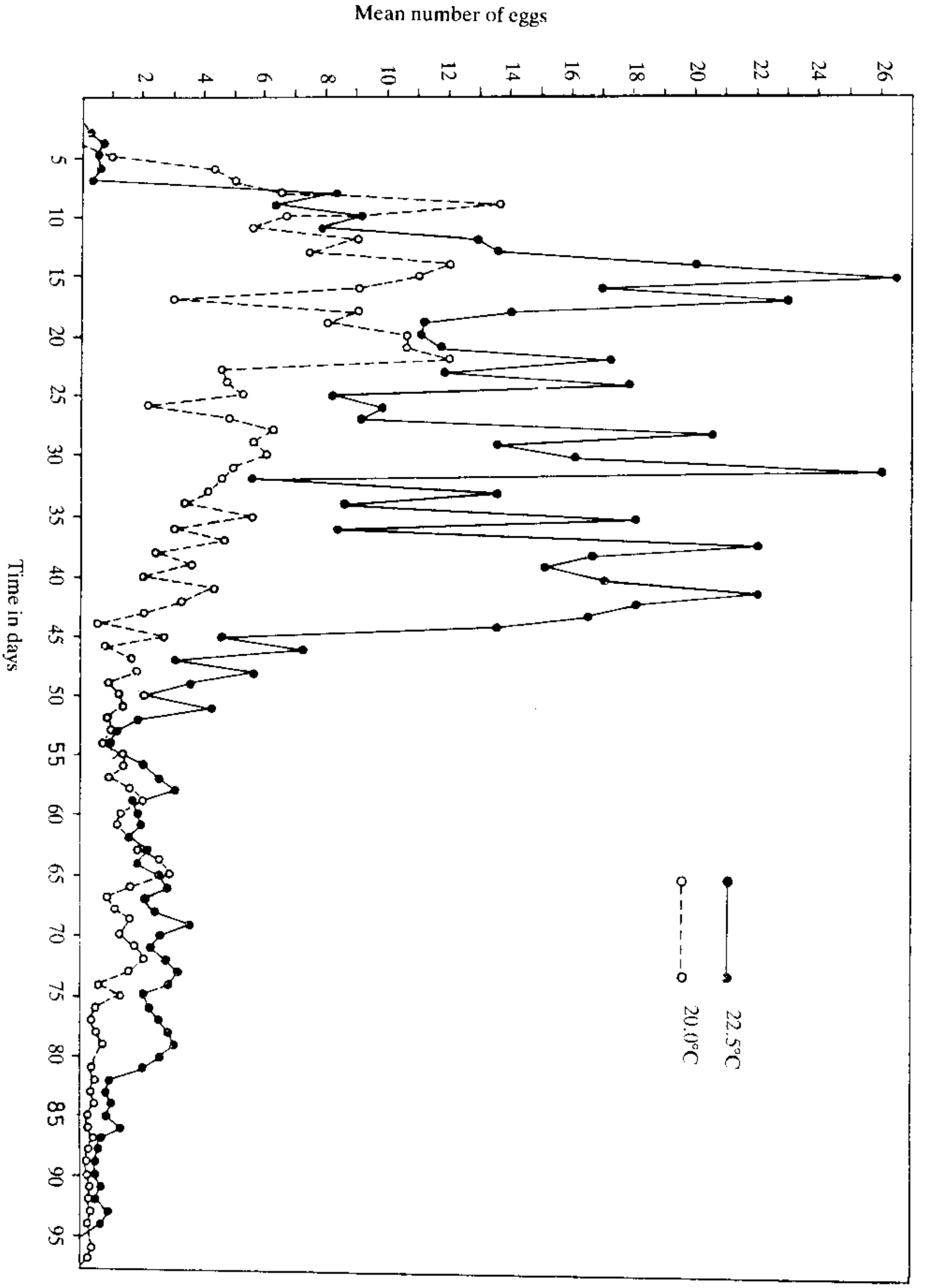

Fig. 3: The mean daily egg production of *Z. indiana* reared at 20 and 22.5°C.

The t and y values derived from linear regression provide an acceptable approximation for estimation field development of some arthropod species [18]. Development thresholds extrapolated from the model can help predict when the insect, in a state of inactivity may vitiate control attempts, as well as when development and growth of population may be increasing. In the present study the lower recorded threshold of *Z. indiana* lies at 10.07 for male and 10.13°C for female. Combining this finding with our previous data given in Amoudi *et al.* [3] which showed that the upper temperature limit for fly development and longevity lies between 30-35°C, we might conclude that the optimum temperature which allows the fly to develop successfully ranges from 20-30°C. This temperature profile might explain the successfulness of the fly in the Al-Sarawat mountain range where the temperature has suitable weather throughout the year, rather than beyond the Al-Sarawat mountains. The climate at Al-Sarawat mountains is very mild throughout the year and these areas constitute the main summer resorts of the Kingdom. Elsewhere, in the country, the general climate is mild in winter, very hot and dry in summer and the temperature exceeds 45°C in most localities (data were obtained from the Hydrology Division, Ministry of Agriculture and Water).

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تأثير درجات الحرارة المنخفضة على نمو وعمر وخصوبة ذبابة زابريونس انديانا *Zaprionus indiana* Gupta التابعة لعائلة الدروسوفيلا من رتبة ثنائية الجناح في المختبر

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ملخص البحث. أجريت هذه الدراسة على ذبابة *Z. indiana* Gupta في المختبر لمعرفة تأثير بعض درجات الحرارة الثابتة على مدى نمو الأطوار غير اليافعة وعلى عمر الذكور والإناث ومعدل وضع البيض.

استخدمت البيانات لإيجاد نموذج يربط درجات الحرارة بالأيام (حرارة/ أيام) اللازمة لإتمام النمو (DD) للتنبؤ بكثافة هذه الذبابة في الحقل. وقد قدرت بـ ٢٢٧,٣ DD للذكور و ٢٠٨,٣ DD للإناث. وكانت درجات الحرارة الدنيا التي يمكن أن يتم عندها النمو من طور البيضة إلى الحشرة البالغة هي ١٠,٠٧°م للذكور و ١٠,١٣°م للإناث. كما دلت النتائج على أن متوسط عمر الذكور كان ٨٠,٩ يوم ومتوسط عمر الإناث كان ٨٨,٩ يوم على درجة حرارة ١٥°م وقد انخفضت الأعمار إلى ٤٦,٣ يوم للذكور و ٥٢,٩ يوم للإناث على درجة حرارة ٢٢,٥°م. وأظهرت النتائج الإحصائية أن نسبة موت البيض على درجات الحرارة المختبرة كانت مرتفعة عن نسبة موت اليرقات أو العذارى. كما بلغ متوسط عدد البيض الذي وضعته الأنثى ٢١٨,٢ بيضة على درجة حرارة ٢٠°م ارتفع إلى ٣٩٥,٨ بيضة على ٢٢,٥°م. وقد كانت نسبة البيض الذي وضعته الأنثى في خلال الـ ٤٥ يومًا من بداية وضع البيض هي ٨٧,٤٪ و ٨٨,٨٪ من عدد البيض الكلي على درجات حرارة ٢٠°م و ٢٢,٥°م على الترتيب.