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Research Article

Effect of Temperature on Development, Sexual Maturation Time, Food Consumption and Body Weight of *Schistocerca gregaria* Forsk. (Orthoptera: Acrididae)

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Abstract: This study was carried out to determine the effect of temperature on the development, sexual maturation time, food consumption and body weight of *S. gregaria*, Forsk., at 25 and 30ºC. The insects were fed on fresh wheat sprouts (FWS) and bran (B). When the temperature was increased, both developmental time and attainment time to sexual maturation were shortened. Total nymphal developmental time at 25 and 30ºC was 32 and 22 days, respectively. Similarly, the average attainment time to sexual maturity was 33 days at 30ºC, whereas it was 52 days at 25ºC. The food consumption of the insects increased at higher temperatures until the end of the first week of adult life and decreased thereafter. From the first nymphal stages to the end of the first week of adult life, each animal consumed 23.82 g FWS and 4.27 g B at 25ºC, and 25.41 g FWS and 4.27 g B at 30ºC. However, from the second week of adult life to sexual maturation, the food consumed by each insect reared at 25ºC was 10.81 g FWS and 1.01 g B, whereas at 30ºC it was 6.97 and 0.84 g, respectively. At the end of experimental period, the final weight of the insects reared at 25 and 30ºC was about the same.

Key Words: *S. gregaria*, development, sexual maturation, food consumption, body weight

Sıcaklığın *Schistocerca gregaria* Forsk (Orthoptera: Acrididae)'da Gelişme, Eşeysel Olgunlaşma, Besin Tüketimi ve Vücut Ağırlığına Etkisi

Özet: Bu çalışma, sıcaklığın *S. gregaria*' da gelişme, eşeysel olgunlaşma süresi, besin tüketimi ve vücut ağırlığına etkisini belirlemek amacıyla 25 ve 30°C sıcaklıklarda yapılmıştır. Böcekler taze buğday çimi ve kepekle beslenmiştir. Sıcaklık arttırıldığında hem gelişme süresi hem de eşeysel olgunlaşma süresi kısaldı. 25 ve 30°C de toplam nimfal gelişme süresi sırasıyla 32 ve 22 gün oldu. Benzer şekilde ortalama eşeysel olgunluğa ulaşma süresi 30°C de 33 gün olurken 25ºC de 52 gün oldu. Böceklerin besin tüketimi ergin hayatın ilk haftasının sonuna kadar sıcaklık artışıyla birlikte arttı, daha sonra azaldı. Birinci nimf evresinden ergin hayatın ilk haftasının sonuna kadar her hayvan 25°C de 23,82 g buğday çimi ve 4,27 g kepek tüketirken 30°C de 25,41 g buğday çimi ve 4,27 g kepek tüketti. Bununla birlikte ergin hayatın ilk haftasından eşeysel olgunluğa kadar 25°C de yetiştirilen her böceğin besin tüketimi 10,81 g buğday çimi ve 1,01 g kepek olurken, 30°C de sırasıyla 6, 97 ve 0,84 g oldu. Deneysel sürenin sonunda 25 ve 30°C de yetiştirilen böceklerin vücut ağırlıkları yaklaşık olarak aynıydı.

Anahtar Sözcükler: *S. gregaria*, gelişme, eşeysel olgunlaşma, besin tüketimi, vücut ağırlığı

Introduction

The desert locust, *S. gregaria*, Forskal, is one of the most economically important species of grasshopper that affect various crops and plants. As a result of it having fast mobility and a broad spectrum of feeding habits on different kinds of crops and plants, it can suddenly and severely damage a wide variety of agricultural fields (1).

It is already known that temperature plays an important role in the different biological activities of poikilothermic organisms (2-7) since these activities depend on temperature-dependent chemical reactions that are limited by lower and upper thresholds (6,8,9).

Understanding the relationship between temperature and various biological characteristics is needed for the development of reliable pest population prediction systems and management strategies. Therefore, we initiated a study to quantify the effects of temperatures on development, sexual maturation time, food consumption, and body weight of *S. gregaria*.

Materials and Methods

A laboratory stock colony of *S. gregaria* was established with nymphs and adults obtained from Ankara University in Turkey. The insects were placed in

an insect-rearing cage (40x40x40cm) at 25±2°C and 50±5% RH. They were reared on fresh wheat sprouts and bran. Water was supplied to the insects in petri dishes with moistened cotton. In the experiments, the offspring of the F_3 generation were used.

The experiments were performed with one-day-old first stage nymphs of *S. gregaria*. Thirty nymphs were taken randomly from the stock cage and separated into two equal groups. One of the groups was kept in an insect-rearing cage at the laboratory conditions mentioned above. The other group was maintained at 30±2°C and 50±5% RH conditions. All experiments were done under natural light conditions. Fresh wheat sprouts (FWS) (50 g) and bran (B) (10 g) were supplied to each group. At 48 hour intervals, FWS and B were removed from the cages and renewed. Both FWS and B were provided throughout the study. The weight of the uneaten food was determined by the original weight minus the final weight. Then food consumption for each individual was calculated by dividing the total weight of consumed food by the number of individuals.

At the beginning of experiments, one-day-old first stage nymphs were weighed and this processes was carried on each week until they attained sexual maturity.

The total duration of all nymphal stages and the attainment time to sexual maturity of adults were considered to determine total developmental and sexual maturation time.

All experiments were repeated three times for each temperature. Differences between the results were analyzed using t and F tests.

Results

The duration of nymphal periods of *S. gregaria* at 25 and 30°C are presented in Table 1 and Figure 1.

As shown in Table 1, the effects of temperature on nymphal developmental periods were highly significant ($P<0.05$). Average nymphal developmental time at 25 and 30°C was 32 and 22 days, respectively.

The results of the experiment dealing with the influence of temperatures on the sexual maturation time of adult *S. gregaria* are shown in Table 2 and Figure 2.

As shown in Table 2 and Figure 2, maturation time was much longer at 25°C than that of 30°C. The average maturation duration was 33 days at 30°C, whereas it was 52 days at 25°C. These differences were statistically significant ($P< 0.05$).

Table 1. Duration of nymphal periods of *S. gregaria* individuals at two temperature regimes.

Temperature (°C)	n	Nymphal Periods (Days)		
		Min.	Max.	Mean ± SE*
25	15	31	33	32 ± 1.41 a
30	15	20	24	22 ± 2 b

* Means within the same column followed by different letters are statistically significant, $P<0.05$.

Table 2. Effect of temperature on sexual maturation time in *S. gregaria* adults.

Temperature (°C)	n	Sexual Maturation Time (Days)		
		Min.	Max.	Mean ± SE*
25	15	50	54	52 ± 1.73 a
30	15	31	35	33 ± 1.73 b

* Means within the same column followed by different letters are statistically significant, $P<0.05$.

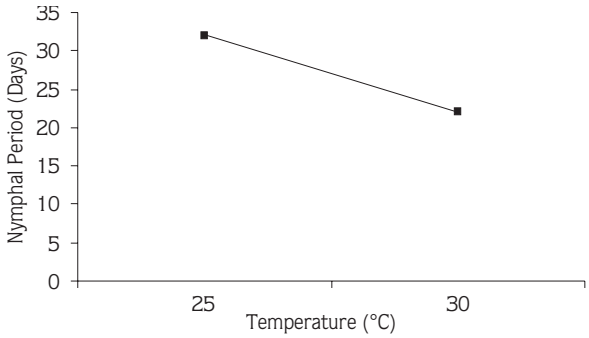

Figure 1. Duration of nymphal periods of *S. gregaria* individuals at two temperature regimes.

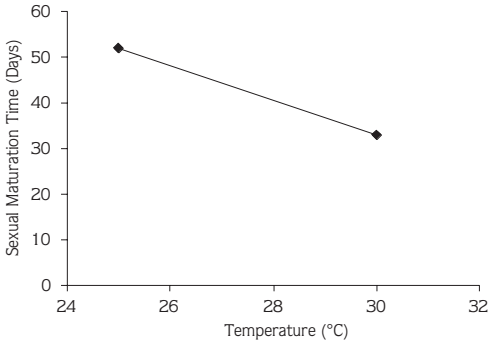

Figure 2. Effect of temperature on sexual maturation time in *S. gregaria* adults.

The results of the experiments concerning average food consumption for the nymphs and adults of *S. gregaria* at the two temperature regimes was given in Table 3, and Figure 3.

As seen in Table 3 and Figure 3, food consumption increased from the first nymphal stage to the end of first week of adult life. This increase was directly proportional to temperature increase. During this period, each animal consumed 23.82 g FWS and 4.27 g B at 25ºC, whereas at 30ºC the same values were 25.41 g and 4.27 g, respectively. However, the food consumption of adults decreased from the end of the first week of adult life to sexual maturation time as the temperature increased. At this time, the food consumption of each insect reared at 25ºC was 10.81 g FWS and 1.01 g B, whereas at 30ºC it was 6.97 and 0.84 g, respectively.

The results of the experiments regarding body weight gain and temperature was given in Table 4 and Figure 4.

Despite the temperature related differences in the rate of weight gain, the final weight attained at the end of the experimental period was not significantly different. For example, 49-day-old individuals had 2.56 and 2.68 g body weight at 25 and 30°C, respectively.

Discussion

Temperature is one of the most important abiotic factors affecting the rates of development time, survivorship, adult size, reproduction, feeding, and gowth of poikilotherms (2-7). This is because each of these physiological processes requires energy obtained from temperature-dependent chemical reactions that are restricted by lower and upper thresholds (6,8,9). It is well known that development does not occur below a low-temperature threshold; above this, the rate increases with temperature until an optimum is reached (9).

Table 3. Food consumption of *S. gregaria* individuals at constant temperature regimes.

Age (Days)	25°C			30°C		
	Life stage	Average Food Consumption of Each Animal (G)*		Life stage	Average Food Consumption of Each Animal (G)*	
		Wheat Sprout	Bran		Wheat Sprout	Bran
0-8	N	1.45 a	0.03 a	N	3.18 a	0.06 a
9-16	N	2.03 a	0.21 b	N	5.69 b	0.86 b
17-24	N	4.44 b	0.64 b	N	7.42 b	1.33 c
25-32	N	7.17 c	1.04 c	A	9.12 c	2.02 d
33-40	A	8.73 c	2.35 d	MA	6.97 b	0.84 b
41-48	A	6.74 c	0.64 b	MA	5.75 b	0.46 b
49-52	MA^+	4.07 b	0.37 b	MA	3.72 a	0.22 a

* Means followed by the same letter within the same column are not statistically significant, P<0.05. N: Nymph, A: Adult, MA: Mature adult, MA^+: Mature adult on the 52nd days.

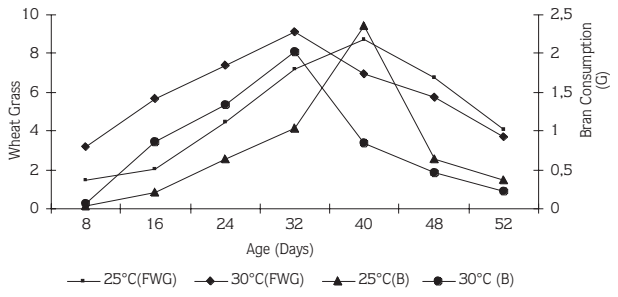

Figure 3. Food consumption of *S. gregaria* individuals at constant temperature regimes.

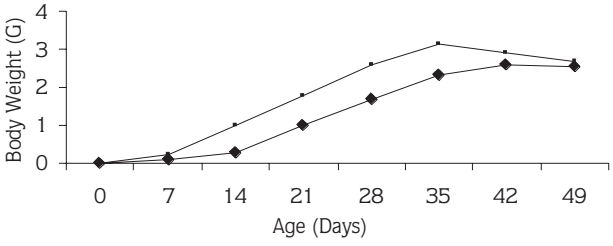

Figure 4. Body weight gain of *S. gregaria* individuals at two temperature regimes.

Table 4. Body weight gain of *S. gregaria* individuals at two temperature regimes.

Age (Days)	25°C			30°C		
	n	Body Weight (G)		n	Body Weight (G)	
		Total	Mean ± SE		Total	Mean ± SE
0-6	15	0.27	0.02 ± 0.07 a	15	0.26	0.02 ± 0.06 a
7-13	15	1.28	0.09 ± 0.32 a	11	2.73	0.25 ± 0.78 a
14-20	13	3.50	0.27 ± 0.93 a	11	10.8	0.98 ± 3.11 a
21-27	13	13.22	1.02 ± 3.52 b	11	19.69	1.79 ± 5.66 b
28-34	13	21.97	1.69 ± 5.85 c	11	28.32	2.58 ± 8.14 c
35-41	13	29.92	2.30 ± 7.97 c	10	31.30	3.13 ± 9.39 c
42-48	12	30.96	2.58 ± 8.55 c	7	20.44	2.92 ± 7.15 c
49-55	11	28.22	2.56 ± 8.11 c	6	16.07	2.68 ± 5.98 c

* Means followed by the same letter within the same column are not statistically significant, $P<0.05$.

Our results showed that at 25°C, the developmental and sexual maturation time of *S. gregaria* individuals was relatively longer than those reared at 30°C. The average developmental time at 25°C was 32 days, whereas it was 22 days at 30°C. The extension of the development time of nymphs delayed the attainment time to sexual maturation. For this reason, the average sexual maturation time for insects was 52 and 33 days, respectively. Differences in these values may be the result of fast physiological changes during developmental time. Similar results were reported for other insect species (10-16). Whitman (10) stated that *Taeniopoda eques* (Orthoptera: Acrididae), from the first stage nymphal period to the adult stage, required 60 and 35 days at 25 and 30°C, respectively. Similarly, Woodson and Edolson (11) observed that *Listronotus texanus* (Coleoptera: Curculionidae), from egg to adult, needed about 65 and 30 days at 20 and 27.5°C, respectively. Parker (16) also noted a similar response in the migratory grasshopper, where a temperature increase from 27 to 32°C decreased the length of larval development by 27 days.

The food consumption and body weight of insects were also affected by temperature (4,5,7,13,17).

Our data indicates that the food consumption of insects increased at higher temperatures until the end of the first week of adult life and decreased thereafter (Table 3 and Figure 3). Until the beginning of the second week of adult life, each animal consumed 23.82 g FWS and 4.27 g B at 25ºC, whereas at 30ºC the same values were 25.41, and 4.27 g, respectively. Henceforth, the food consumption of adults decreased from the end of the first week of adult life until sexual maturation. During this experimental period, the food consumption of each insect reared at 25ºC was 10.81 g FWS and 1.01 g B, whereas at 30ºC temperature it was 6.97 g and 0.84 g, respectively. These results agree with the findings of Hill et al. (17). They stated that the feeding activity in the female desert locust is intense during the first week of adult life, but lower thereafter. Roe et al. (5) reported similar results in the female house cricket, *Acheta domesticus*. They found that the rate of food consumption was highest during the first half of the eighth stadium at 35°C, compared with the 30 and 25°C.

As shown in Table 3 and Figures 3 and 4, the consumption amount of each food type at the two temperatures was not the same. For instance, at 25°C, during the experimental period, the FWG consumption of each animal was 34.63 g, whereas B consumption of the same insect was 5.28 g. This might have resulted from the water content and colors of food.

Our results also suggest that a high rate of food consumption from the first day of nymphal life to the beginning of adult life resulted in a coincidental high weight gain, but the average weight gain at the end of experimental period was not significantly different. Roe et al. (5) showed that the maximum dry weight during the eighth stadium of a female house cricket at 25, 30 and 35°C averaged within a 6 mg range and was not significantly different. A similar phenomenon was reported by Beenakkers et al. (4). They found, that

although the gowth rate was different, the maximum weight of fifth instar *Locusta* reared at 25 and 31°C was about the same. Beenakkers et al. (4) drew a conclusion from this that a certain critical weight must be reached before apolysis and ecdysis will occur. It may be assumed that *S. gregaria* adults attained "critical weight" at the end of first week of adult life and the temperature variation did not affect the size of critical weight, but it especially affected the attainment time of critical weight. This period coincided with a reduction in the food consumption rate of the 2-week-old adults. At the end of the experimental period, we also observed that there was a weight loss in adults from the second week of adult life until sexual maturation. This is because the geater part of obtained energy was used for sexual activity and oviposition.

In summary, a controlled study can provide a valuable insight into the population dynamics of a particular species, even though in nature insects are not subject to constant temperatures (9). For this reason, the models developed from these results can be used to determine the developmental time, sexual maturation time and food consumption of *S. gregaria* individuals under natural conditions. To develop sustainable pest management programs, these results should be considered.

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