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Effect of Temperature on Development and Reproduction of the Emma Field Cricket, *Teleogryllus emma* (Orthoptera: Gryllidae)

Namjung Kim*, Seong Jin Hong, Kwang Youl Seol, Seong Hyun Kim, Nan Hee Ahn and Mi Ae Kim
Department of Agricultural Biology, National Institute of Agricultural Science & Technology, RDA, Suwon 441-100, Korea

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To establish the indoor-rearing system of the emma field cricket, *Teleogryllus emma,* the effects of temperature on development and reproduction of the emma cricket have been studied. The influence of temperature on developmental periods of emma field cricket was investigated under the eight temperatures of 15, 18, 21, 25, 27, 29, 31 and 35°C, under 60±5% R.H. and 16L : 8D photoperiod. The developmental periods of *T. emma* nymphs had a range of 124.8 days to 44.4 days at the temperature of 21°C and 35°C, respectively. At 15°C and 18°C, however, all tested individuals died before emergence. The highest survival rate was 90% at 25°C, but there were no statistically significant differences among the temperatures. The adult weight increased with increasing temperatures although the weight at 35°C was decreased. In addition, the influence of temperature on reproduction of emma field cricket was investigated under three temperatures 22 °C, 25°C and 28°C, under 60±5% R.H. and 16L : 8D photoperiod. The longevity of female/male adults were 65.8/79.2 days, 68.5/67.8 days, 46.8/57.4 days at the temperature 22°C, 25°C and 28°C, respectively. The preoviposition periods were 32.5 days at 22°C, 22.9°C days at 25°C and 22.1 days at 28°C. The highest average fecundity per female was 737.3 at 25°C.

Key words: Cricket, *Teleogryllus emma,* Temperature, Development, fecundity

*To whom the correspondence addressed
Department of Agricultural Biology, National Institute of Agricultural Science & Technology, RDA, Suwon 441 - 100, Korea. Tel: 82-31-290-8559, Fax: 82-31-290-8543; E-mail: vastnj@rda.go.kr

Introduction

Crickets are probably the best all around fish bait in the world, as well as a live food for many types of pets. Field crickets (Gryllinae, especially Gryllus spp.) have many advantages for use in field and laboratory studies of insect ecology and behavior (Choo and Choi. 1983; Doherty and Storz 1992; Gray, 1999; Fitzpatrick and Gray 2001; Bertram, 2002). They are widely distributed, easily collected, large in size, easily sexed. However, relatively little is known about their developmental characteristics, particularly *Teleogryllus emma*. The emma field cricket, *Teleogryllus emma* is one of the most conspicuous and widely distributed in the Korea. This species undergoes an embryonic diapause and produces one generation a year. The nymph hatches in late spring or early summer and matures in autumn. The adult lays diapause eggs in the damp soil (Bae, 1998). Of the many possible factors that many affect the rate of cricket growth, temperature is probably the most important.

The purpose of the present study was to determine the developmental duration of *T. emma* from eggs to adults and the fertility of the females under constant temperatures.

Materials and Methods

Insects

T. emma were obtained from fields in Suwon region of Korea in September 2002. Rearing of the crickets was carried out in the laboratory regulated at 28±1°C, 60% R.H. under a 16 h light 8 h dark photoperiod. The *T. emma* had been reared in laboratory for above 1 year before individuals were used in the experiments (Kim *et al*, 2005). Hatched nymphs were individually reared in a plastic container at the same conditions mentioned earlier. The var-

ious plastic containers were used for rearing as follows: a small (9.0 cm diameter and 1.5 cm height) for the 1st through the 4th, and a large size (15.0 cm diameter and 2.5 cm height) for the 5th through the 9th. Artificial diet was sufficiently fed to the 1st through the 4th nymph in a container with wheat bran and water by using flower foam (4 cm × 2 cm × 2 cm), and the 5th through the 9th nymph, with wheat bran mixed with 40% fish powder added as food and distilled water provided in a small container with artificial cotton (4 cm × 2 cm × 2 cm) placed at the bottom.

Effects of temperature on the developmental characteristics

The nymphal development was determined at eight constant temperatures (15, 18, 21, 25, 27, 29, 31, and 35°C under a photoperiod of 16L : 8D) in the growth chamber. The nymphal development was measured in each group. nymphal period, survival rate of each group were determined as follows. Thirty newly hatched nymphs were placed on an artificial diet and held at various temperatures. The nymph was examined daily, and food was added as needed. Periods and survival rate of each instar were also determined.

Effects of temperature on the adult longevity and fecundity

In order to examine the adult longevity and fecundity for each temperature, research was carried out in the rearing room at 22, 25, and 28°C under a 16L : 8D photo regimen. Temperature in rearing room was regulated by air cooling and hearting thermostat. In order to randomize temperature differences between acrylic boxes, the acrylic boxes were daily transferred from one to other acrylic box in a regular sequence. A pair of new male and female adults were placed inside an acrylic box (20 cm × 10 cm × 15 cm), with wheat bran mixed with 40% fish powder added as food and distilled water provided in a small container with artificial cotton placed at the bottom. In order to examine their longevity and fecundity, their survival condition was examined every day at the same time, and for oviposition mat, fine soil was wet with moisture and placed inside the Petri dish (15.0 cm diameter and 2.5 cm height). Eggs were received every day and the number of eggs laid was counted. Also, in order to examine the characteristics of oviposition when they are being bred in a group, ten pairs of new male and female adults were placed in a box with the exact same conditions as the above and researched in the same way.

Statistical analysis

Differences in developmental period, adult weight, Longevity and fecundity were tested by analysis of variance (ANOVA). If significant differences were detected, multiple comparisons were made using Tukey's HSD multiple range test($P = 0.05$)

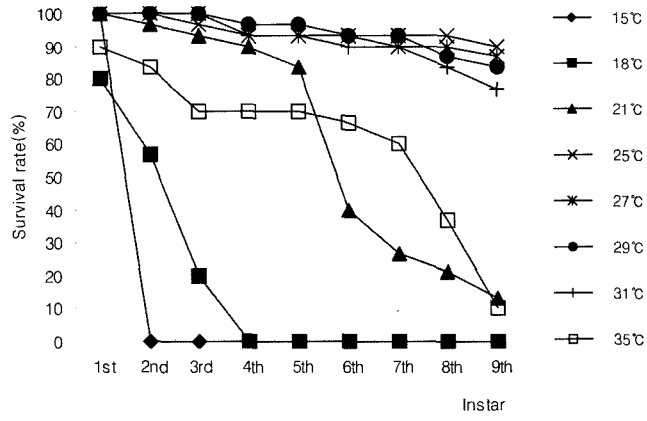

Fig. 1. Survival rate of each instar of *T. emma* at the various temperatures. The nymphs were reared under a photoperiod of 16L : 8D.

Results and Discussion

Effects of temperature on the developmental characteristics

The survival rate of *T. emma* under the eight different temperatures (15, 18, 21, 25, 27, 29, 31, and 35°C) are shown in fig. 1. The mean rate decreased with ascending temperature between 25 and 31. The survival ratio was 90, 87, 83, and 77% at 25°C, 27°C, 29°C, and 31°C, respectively. A temperature of 15°C produced 100% mortality of the first instar, and at 18°C died during the 4th instar. The exposure of nymphs to a constant temperature of 21°C and 35°C decreased the survival rate to nearly 13 and 10%, respectively. The highest survival rate was recorded at 25°C~31°C. The effect of the eight constant temperatures on nymphal developmental time is summarized in table 1. The duration of development was shortest at 35°C. Development from hatched egg to adult was fastest at this temperature, with a developmental time of 47.31 days. The duration of each instar dragged longer, when reared at relatively low rearing temperatures, as compared to that at high rearing temperatures. The duration of each instar also increased as nymphal development progressed. Particularly, the duration of the 8th and the 9th instar at 21°C~29°C was highly prolonged. Figure 2 presents weight of the newly adult according to the different temperatures. The adult weight increased with increasing temperatures although the weight at 35°C was decreased. The Newly adult weight (the female/the male) was 366/281 mg at

Table 1. Duration of nymphal development of *T. emma* at the various temperatures. The nymphs were reared under a photoperiod of 16L : 8D. Means in columns followed by the same letter are not significantly differently by Tukey's HSD multiple range test (P = 0.05)

Temp.	Nymphal instar								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
15°C	37.72 ±11.02a	-	-	-	-	-	-	-	-
18°C	27.50 ±4.09b	22.94 ±8.26a	36.00 ±13.43a	-	-	-	-	-	-
21°C	11.9 ±0.61c	10.69 ±3.36b	9.18 ±2.34b	12.69 ±6.44a	11.13 ±1.61a	22.09 ±7.12a	12.33 ±8.86a	17.40 ±1.52a	22.00 ±3.34a
25°C	6.57 ±0.94d	6.55 ±1.57c	6.62 ±1.40c	5.82 ±0.82b	6.25 ±0.80b	7.54 ±1.10b	7.82 ±0.98b	10.74 ±2.26b	13.93 ±2.96b
27°C	5.07 ±0.25de	4.5 ±0.78d	4.66 ±0.61d	4.93 ±1.18bc	6.00 ±1.44bc	5.59 ±1.24c	6.96 ±1.09bc	9.37 ±1.96c	14.08 ±3.24b
29°C	4.88 ±0.34de	4.5 ±0.59d	4.58 ±0.58d	4.13 ±0.95cd	5.42 ±0.93cd	5.33 ±0.71c	6.04 ±1.12cd	7.96 ±1.73c	11.80 ±2.66c
31°C	4.17 ±0.38e	3.20 ±0.41d	3.73 ±0.58d	4.96 ±1.40bc	4.93 ±1.29d	4.44 ±1.05c	5.26 ±1.27d	9.40 ±3.08d	10.50 ±3.97cd
35°C	3.70 ±1.26de	3.40 ±1.58d	3.52 ±2.54d	3.48 ±0.60d	5.00 ±1.70d	4.65 ±1.95c	7.61 ±2.91b	7.27 ±1.74d	7.67 ±1.53d

-, No measurement due to all death.

21°C, 494/499 mg at 25°C, 698/625 mg at 27°C, 723/613 mg at 29°C, 715/647 mg at 31°C, and 546/400 mg at 35 °C. An interesting observation on fecundity has been reported by Oldiges (1959) for *Galleria mellonella*. Females obtained from larvae reared at 26°C laid more eggs than animals reared at either lower or higher temperatures. At 26°C the larvae consumed more food and consequently became heavier than those reared at other temperatures. The resulting heavier adults laid more eggs than did the lighter ones, a phenomenon which has been reported for a number of other species (Roy, 1936).

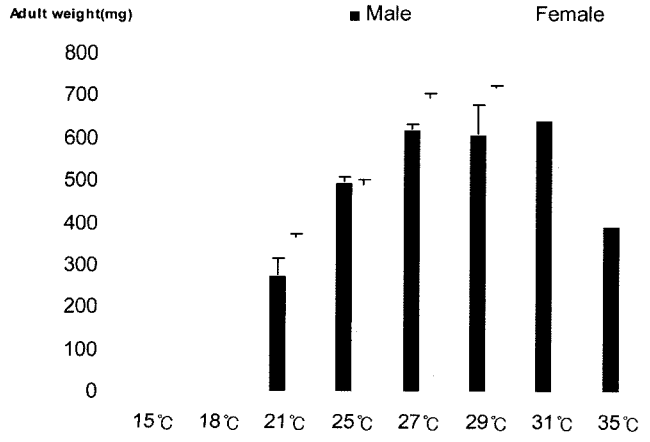

Fig. 2. Adult weight of *T. emma* at the various temperatures. The nymphs were reared under a photoperiod of 16L : 8D. The bar indicates standard deviation.

The experimental results obtained in our study indicate that the developmental biology of *T. emma* is strongly affected by exposure to a constant temperature in the range 15°C to 18°C, with 35°C probably approaching the physiological limit for this cricket. The optimal range of temperature for development of *T. emma* was 27°C~ 31°C.

Effects of temperature on the adult longevity and fecundity

Longevity and the number of eggs laid for each temperature are as the results shown in Table 2. The adult longevity was affected by temperature, and tended to become shorter as the temperature rose. In case of male adults, longevity was 79.2 days at 22°C and 57.38 days at 28°C, showing a regular tendency for shorter span as temperature rose, but in case of female adults, there was no significant difference between 22°C and 25°C, what at still higher temperatures, a tendency for shorter span was observed. The preoviposition period was 32.53 days at 22°C, but from 25°C to 28°C, it remained much the same at about 22 days. The oviposition periods were 26.9 days at 22°C, 34.1 days at 25°C and 21.8 days at 28°C. The number of eggs laid for each temperature, the highest average fecundity per female was 737.3 at 25°C.

After the emergence of female adults, the oviposition curve per day is as shown in Fig. 3. In case of individual breeding, as shown in Figure 3 (Upper), at 22, 25, and 28

Table 2. Longevity and fecundity of *T. emma* on three different temperatures. The adults were reared under a photoperiod of 16L : 8D. Means in columns followed by the same letter are not significantly differently by Tukey's HSD multiple range test (P = 0.05)

Temp.	Preoviposition Period (days)	Oviposition Period (days)	Longevity (days)		Total no. of eggs laid per female
			Female	Male	
22°C	32.53 ± 8.07a	26.89 ± 17.26a	65.80 ± 12.36a	79.20 ± 11.09a	502.16 ± 422.58a
25°C	22.85 ± 11.37a	34.05 ± 17.20a	68.50 ± 13.23a	67.81 ± 6.78ab	737.25 ± 439.20a
28°C	22.10 ± 6.21a	21.79 ± 12.35a	46.75 ± 5.19b	57.38 ± 4.68b	438.50 ± 318.13a

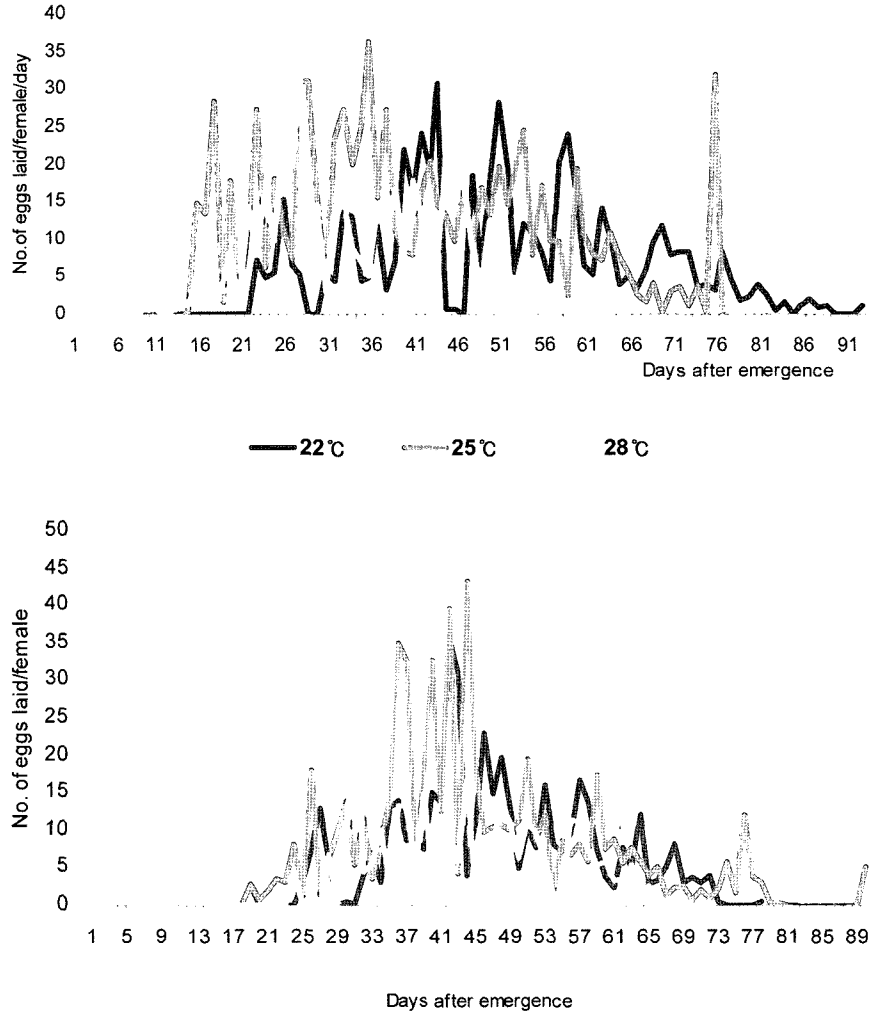

Fig. 3. Daily oviposition by *T. emma* female adult at different temperatures. Individual rearing (Upper), Group rearing (Under).

°C, the peak point occurred in 40 days, 36 days, and 26 days, respectively, showing a tendency for faster oviposition the higher the temperature, but between 22°C~25°C, the peak point was not clear. In case of group breeding, however, as shown in Figure 3 (Under), the peak point was generally clear, and specifically, there was a concentration of long oviposition period at 25°C. Also, the average total number of eggs laid for one female adult was the highest at 25°C, numbering 737.25 eggs. Optimal temperatures for egg output vary greatly among species, possibly reflecting the temperatures the species normally encounter during reproductive periods. The optimum of temperature for the reproduction of *T. emma* was 25°C. On the other hand, migratory locusts generally reproduce best, both in the laboratory and in the field, at temperatures above 30°C (Hamilton, 1936; Popov, 1954); *Schis-*

tocerca gregaria and *Locusta migratoria* rarely if ever lay eggs at temperatures below 20°C (Hamilton, 1936). The experimental results and cases mentioned illustrate some of the principal findings concerning temperature effects. As with any of the environmental factors, the primary site of action of temperature with respect to egg production can only be surmised.

The present results provide data for establishing suitable conditions for rearing. Mass culture methods could be enhanced by selecting temperature conditions for either rapid development or high fecundity.

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