

Effect of temperature on the hatching and post –diapause embryonic development time in Rice grasshopper, *Oxya japonica* (Thunberg) (Orthoptera, Acrididae).

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Abstract: - A study was conducted to assess the effects of six constant temperatures (15, 20, 25, 30, 35 and 40°C) on the post diapause embryonic development (PDD) and the hatching time in rice grasshopper, *Oxya japonica*. Egg hatching and development occurred over the entire range except at 40°C and below 15°C. The relationship between temperature and development rates was analyzed. The PDD duration was strongly temperature dependent and is crucial to the completion of the annual cycle. The optimum temperature range for the hopper development was 35°C. Grasshopper survival exhibited a unimodal response to temperature, with highest survival at intermediate temperatures. The results are useful in predicting how changes in abiotic variables associated with climate change may affect species performance.

[S. Tariq Ahmad & Mir Tajamul. **Effect of temperature on the hatching and post –diapause embryonic development time in Rice grasshopper, *Oxya japonica* (Thunberg) (Orthoptera, Acrididae).** *Nat Sci* 2014;12(6):121-125]. (ISSN: 1545-0740). <http://www.sciencepub.net/nature>. 17

Keywords: Diapause, Post embryonic development, *Oxya japonica*.

1. Introduction

Grasshopper species occupy markedly different habitats, laying their eggs underground in pods (Uvarov 1966; 1977; Stauffer and Whiteman 1997). The development of eggs is influenced by temperature moisture and oxygen levels (Uvarov 1966; 1977; Farrow 1975). The eggs are metabolically active as the embryos develop but oxygen consumption falls during periods when the embryo enters diapause. Temperature also influences developmental rates and may serve as a stimulus for hatching (Uvarov 1966; 1977).

Egg development and environmental factors affecting an insect species are clearly of great importance to their life history, particularly in the temperate regions, where many acridids pass seasonally unfavourable conditions in dormancy (Danks, 1987; Chapman, 1998; Nechols *et al.*, 1998). Effect of temperature on the development of Mediterranean or Moroccan locust, *Dociopterus maroccanus* (Orthoptera, Acrididae) was studied by Bodenheimer and Shulov, 1951; merton, 1959. This principle is applicable to rice grasshopper, *Oxya japonica* (Orthoptera, Acrididae), for which temperature is the most important environmental factor controlling environmental development and dormancy.

Parker (1930) estimated the lower developmental threshold temperature (LDT) of grasshoppers to be 17°C. Studies by Shotwell (1941) on 12 grasshopper species and Pickford (1966) on *Camnula pellucid* also suggested the importance of

springtime soil temperature in driving egg hatching in spring, and they observe that hatching did not occur at soil temperature below 15.6°C. Research on post-diapause embryonic development in *melanoplus bivittatus* by Church and Salt (1952) suggested that the LDT

for normal development was 12°C. In addition to temperature, soil moisture (Mukerje and Gage, 1978), oviposition sites, pod depth, pod orientation, pre-diapause embryonic development, and diapause-terminate conditions in winter (temperature and water) also influence the hatching time of grasshopper eggs in spring (Kemp and Sanchez, 1987). These results help explain some variation found in the hatching time sequence of grasshopper species.

On account of their ability to occupy markedly different habitats some authors have proposed the use of grasshoppers as indicators for different microclimates (Franz 1931, 1933). Differences between the habitats of species have been explained in several ways. Franz (1931, 1933), jacoblev (1957, 1959), Kaltenbach (1963), Schmidt and Buhl (1970) concluded that these are caused by differences in the microclimatological demands of nymphs and imagines. Other authors have concluded that biotic factors are important, eg. the availability (Otte and joern 1977) and competition and predation (Joern, 1982). Uvarov (1966) and Hunter-jones (1970) stressed the importance of high temperature and wated availability for egg development. Ingrisch found that the drought tolerance of the eggs of

species living in moist biotopes is very low. The influence of temperature on the duration of egg development of west European grasshoppers was studied by Wingerden, Musters and Maaskamp, 1991.

Temperature is especially important for insects, influencing many physiological processes such as metabolism, digestion, phenology, behaviour and development (Heinrich 1993). Changes in temperature associated with global climate change may have impacts on insects at both the individual and population level. For example, temperature influences activity time and digestion rates, both of which determine resource intake for individuals (Heinrich 1993, Yang and Joern 1994b, Harrison and Fewell 1995). By influencing resource intake, temperature can affect both survivorship and fecundity.

We report here on the temperature dependent development of *O. japonica* eggs and instar stages and the optimal temperature conditions that are required to complete embryonic development and hatching successfully.

2. Material and Methods

(a) Egg origin and collection

The present research investigations were conducted under laboratory conditions. The adult grasshoppers and various immature nymphal stages of *Oxya japonica* were mostly collected from cultivated rice fields and other surrounding vegetation of grasses from different climatic zones of Kashmir province during months of May-September in the year 2013. The collection of insects was made from 9:00 to 12:00 noon with the help of insect collecting net and kept in rearing cage measuring 112×82×82 cm. Green shoots of fresh leaves cuttings were clipped and placed into 50 ml conical flask filled with water. Two sides of the cage were made of wood, fitted with windows to clear the grasses and transferring the insects. The other two opposite sides were made of glass and wire mesh respectively. The floor of the cage was made of wire mesh provided with six holes each containing the metallic tube, each measuring 11cm in length and 3 cm in diameter, filled with moist sterilized sand which provided pseudo earth for oviposition. The cage was fitted with the temperature apparatus to maintain the constant temperature. Each cage was provided with a number of plant twigs for perching, moulting and for basking. The humidity of the cage was maintained by placing petridish containing moist cotton in the cage.

(b) Preparation of eggs for study

Egg pods were collected from the oviposition cages regularly and transferred to glass jars 15×5 cm, which contained washed sand moistened to the point

of being wet but not fully submerged. Each jar contained one egg pod. To determine the effect of temperature on egg development 40 jars were divided into 6 treatment groups and cultured in incubators at six different temperature viz. 15, 20, 25, 30, 35 and 40°C. Newly hatched instars were fed twice per day as per experimentally designed conditions of food at 65±5% RH. The open end of the jar was covered with muslin cloth held with a rubber band

3. Statistical analysis

Data obtained from experimental groups were subjected to one-way analysis of variance (ANOVA), (MS Excel 2007, PRIMER software) with repeated measures and significant means were determined using Tukey's Multiple Comparison Test (TMCT).

4. Results

Our results show that high temperature generally speeds development of *Oxya japonica*. Mean development period of *O. Japonica* at 15°C was 126.85 ± 3.66 days, which was the maximum period as compared to development observed at higher temperatures. At 20°C, the mean development period was 108.43 ± 2.93 days while at 25°C, 30°C and 35°C it was recorded to be 92.91 ± 2.8, 78.75 ± 2.12 and 64.34 ± 1.27 days respectively. At 40°C no hatching of egg pods was observed.

The mean hatching period was 25.5±1.52 days at 15°C, 21.01±0.85 days at 20°C, 16.45±1.05 days at 25°C, 14.35±1.26 days at 30°C and 11.23±0.65 days at 35°C. The development rates of 1st instar were significantly different ($p < 0.05$) at various temperatures except at 25°C and 30°C ($p > 0.05$). No hatching occurred at 40°C. 1st instar showed rapid development at 35°C. Mean development period for 1st instar was 16.9±1.36 days at 15°C, 15.2±0.76 days at 20°C, 12.2±1.01 days at 25°C, 10.5±0.08 days at 30°C and 9.8±0.21 days at 35°C. However, the development period for 1st instar at 15 and 20°C, 30 and 35°C was found to be statistically insignificant ($p > 0.05$).

In case of Second instar the mean development period was 18.8±1.02, 16.62±0.55, 14.5±0.65, 12.8±1.02 and 10.6±1.32 days at 15, 20, 25, 30 and 35°C respectively. The differences between development periods were found to be significant for all temperatures ($p < 0.05$). Third instar also showed fastest development at 35°C. The mean development periods for third instars were found to be 21.6±0.99, 18.2±0.95, 16.4±1.36, 13.5±1.25 and 11.2±0.95 at 15, 20, 25, 30 and 35°C respectively.

Development rates for fourth instars were also found to be significantly different at different temperatures with maximum development period of 24.55±0.21 recorded at 15°C and minimum

development period of 13.25 ± 1.21 recorded at 35°C . For fifth hopper instar the development periods were 19.5 ± 0.11 , 15.2 ± 0.21 , 13.36 ± 0.13 , 11.3 ± 0.41 , 8.24 ± 0.51 days at 15, 20, 25, 30 and 35°C respectively. The differences in development periods were found to be significantly different at various temperatures.

Summing up these readings, it was concluded that the optimum temperature for the hopper development was 35°C . The developmental rates showed a progressive increase with increase in temperature upto 35°C . However, at 40°C hatching of hopper egg pods was not observed.

Table 1: Effect of Temperature ($^\circ\text{C}$) on the post embryonic developmental stages of *Oxya japonica*.

Mean post embryonic development period in days of instars in days \pm SD							
Treatment $^\circ\text{C}$	Hatching	I	II	III	IV	V	Total
15	25.5 ± 1.52^a	16.9 ± 1.36^a	18.8 ± 1.02^a	21.6 ± 0.99^a	24.55 ± 0.21^a	19.5 ± 0.11^a	126.85 ± 3.66^a
20	21.01 ± 0.85^b	15.2 ± 0.76^a	16.62 ± 0.55^b	18.2 ± 0.95^b	22.2 ± 0.54^b	15.2 ± 0.21^b	108.43 ± 2.93^b
25	16.45 ± 1.05^c	12.2 ± 1.01^b	14.5 ± 0.65^c	16.4 ± 1.36^c	19.8 ± 0.87^c	13.36 ± 0.13^c	92.91 ± 2.8^c
30	14.35 ± 1.26^c	10.5 ± 0.08^c	12.8 ± 1.02^d	13.5 ± 1.25^d	16.3 ± 0.95^d	11.3 ± 0.41^d	78.75 ± 2.12^d
35	11.23 ± 0.65^d	9.8 ± 0.21^c	10.6 ± 1.32^e	11.2 ± 0.95^e	13.25 ± 1.21^e	8.24 ± 0.51^c	64.34 ± 1.27^e
40	No Hatching						
F	257.18*	66.38*	56.27*	66.04*	147.5*	877.31*	417.55*

Note: Mean in the same column followed by the same letter(s) are not significantly different from one another at 5% level of probability (TMCT), ns-not significant, $p \geq 0.05$.

4. Discussions

The experiment clearly reveals that the hatching and post embryonic development of the *O. japonica* is significantly affected by temperature. Among various treatments, rearing of hoppers at 35°C resulted in the shortest nymphal development period. In contrast, rearing at 15°C led to the prolonged nymphal development period. However, high temperatures (above 35°C) negatively influence the eggs of *O. japonica*, incubation periods increased as temperature increased beyond 35°C .

Our results confirm that temperatures $> 35^\circ\text{C}$ and $< 15^\circ\text{C}$ lead to delay of the embryonic development (Quesada-Moraga and Santiago-Alvarez, 1999) and suggest some adaptive significance. This may explain the retardation of development in stage I, observed under field conditions both by Bodenheimer Shulov (1951) in Iraq, because the mean temperatures in these areas at the time of oviposition are usually higher than 30°C . The delay in the development is probably a response to immediately adverse conditions, quiescence that can be averted by temperatures lower than 35°C .

These results may help us to understand the life cycle strategy of *O. japonica*. After oviposition, late autumn, temperatures are usually lower than 15°C . Therefore, the rate of development of the embryos is very slow or does not take place. This explains the observed quiescence in field conditions (Bodenheimer & Shulov, 1951; Hernandez-crespo, 1993; Quesada-Moraga, 1998). With the increasing

temperatures in the early summer, development is accelerated, ensuring hatching in spring as the conditions are favourable for the survival of nymphs.

Additionally, the adaptation of grasshoppers to environment should include other two aspects. One is the cold hardiness of grasshoppers and their overwintering ability. According to our observations, pre-diapause and diapause embryonic stages could safely survive in severe winter temperature conditions (Hao and Kang, 2004). Another aspect is that grasshoppers require special nourishment that may be present in a particular host plant to meet the growth and development of their instar nymphs. Although this has not been confirmed by experiments.

Acknowledgements:

The authors are grateful to Head, Department of Zoology, Kashmir University for providing research facilities.

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5/23/2014