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Effect of Temperature on the Growth of the Water Strider, *Gerris paludum insularis* (Gerridae, Heteroptera)

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ABSTRACT : The water strider, *Gerris paludum insularis*, was reared in a growth cabinet at two constant temperatures and ≈20℃ under a 16:8 (L:D) photoperiod. Differences in head width among three temperatures of ≈20℃, 25℃ and 30℃ in *G. paludum insularis*, were compared. Temperature affected growth of head width of *G. paludum insularis*. There were highly significant differences among head width for three temperature regimes and the immature stages. It was found that head width is greater in 30℃ than 25℃ and ≈20℃. The growth quantity of the head width in ≈20℃ shows the slowest increase, and 25℃ and 30℃ were gradually increased in that order. The maximum ratio of growth quantity by each stage is in the first instar in all regimes. The growth rates of all regimes show an increase pattern.

Key words : Dyar's law, *Gerris paludum insularis*, Growth, Quadratic equation, Rearing, Temperature

INTRODUCTION

Temperature is an important limiting factor in aquatic environments, and thermal pollution can cause local detrimental effects on an aquatic ecosystems (Odum 1971).

Individual body size is often related to fitness in insects and other animals (Bosch and Vicens 2002). Insects can perceive small differences in air temperature. *Cimex* (Heteroptera), for instances, is sensitive to change of less than 1℃, and bees can be trained to select one of two temperatures differing by only 2℃ (Chapman 1982).

Being poikilothermic, the rate of development in insects is governed by ambient temperature; the higher the temperature, the faster development occurs (Ames and Turner 2003). Therefore, thermal pollution may affect the distribution and development of all stages in the life histories of aquatic insects. Moss (1980) showed that temperature has a major effect on the growth rates of poikilothermic animals and relatively small increases in temperature can change the species composition of aquatic invertebrate and fish communities.

The water striders are semiaquatic territorial insects that occupy the littoral neuston of ponds and streams. They are secondary consumers that feed chiefly on other insects associated with or trapped on the surface film. Water striders are common and conspicuous aquatic insects and are therefore potentially useful biological indicators (Park 1988). The insects change in size and weight of each part of the body through the moulting of the developmental stages. In many insects, the amount of growth is achieved at each moult. According to empirical laws of growth known as Dyar's law the head width is increased at each moult by a ratio of about 1.4 which is constant for given species.

Head width is probably one of the most slowly growing parts of the body and is expected to be negatively allometric against most reference size during the postembryonic development (Rensch 1959). Matsuda (1962) indicated that the head width is good fit for the description of growth pattern of insects. The width of head was chosen as the standard measurement because it is the most stable part of the body and least subject to change in size owing to changes in the physiological state of the individual (Mukerji 1972).

This study examines the effect of temperature on the growth of the head width of the water strider, *Gerris paludum insularis* (Motschulsky) (Gerridae, Heteroptera) taken from given population near Taegu, South Korea.

MATERIALS AND METHODS

Adults *G. paludum insularis*, collected from streams in the suburbs of Taegu, South Korea, were maintained in an aquarium (60 by 30 by 50 cm) contained in a Hotpack Model 462 growth chamber (Hotpack, Philadelphia) set. The growth cabinet was controlled at two constant temperatures of 25 and 30℃. And laboratory group was reared at uncontrolled environment, shade temperature of about 20℃ in the windows opened. The growth cabinet photoperiod was maintained at 16:8 (L:D) at a light intensity of 510 lux and at 65% constant relative humidity. Photoperiod and a light intensity

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were of a sort in control and uncontrolled groups of temperature.

Water temperature in the aquarium was always 2 to 3℃ below the cabinet air temperature. The water was changed three times a week and six fruit flies (*Drosophila melanogaster* Meigen) reared on apple medium were presented to each gerrid twice a day.

Newly collected adults of unknown age were permitted to lay eggs for 6 hrs and then removed. An insect spreading board wrapped in sheer nylon taffeta was floated on the water to provide an oviposition substrate. The eggs were incubated in the aquarium. The eggs were checked for eclosion twice a day at 0900 and 2100 hours. During nymphal development, the aquarium was checked twice a day for exuviae to determine when ecdysis occurred. If molting or hatching was anticipated, an additional observation was made in the late evening.

Unimpaired specimens were selected and measured. The larvae were preserved in alcohol, but the adult specimens were dried, one day after molting. All measurements were made at units irrespective of sex under the stereoscopic microscope with a linear micrometer.

The author employed a growth formula for growth. Growth formula is the common way of expressing the corresponding change of the growth quantity (GQ) in time t in each lnstar. The growth formula can be expressed by a quadratic equation $y=a+bt+ct^2$. This equation states that y is a function of time t in each instar. The value of y means the length in ㎜, the growth quantity determined by the time t in each instar. That is the value of y depends upon the time t in each instar. This formula gives the growth rate (GR), mathematically the first delivative, $dy/dt=b+2ct$. The data were analyzed by an analysis of variance, with Duncan's multiple range test.

RESULTS AND DISCUSSION

Table 1 gives the measurements of head width for three temperatures regimes for the six developmental stages in *G. paludum insularis*. Employing the rectangular coordinate system for the geometric interpretation, the author projected the trend line.

Temperature affected growth of head width of *G. paludum insularis* as indicated in Table 1. There were highly significant differences among head width for three groups and the immature stages. It was found that head width are greater in 30℃ than in 25℃ and ≈20℃ (P<0.01).

The regression equations describing the relationship between temperature and growth are given in Table 2. Applying the quadratic growth formula, $y = a + bt + ct^2$ to the mean values of the original measurements of head width in the developmental stages of *G. paludum insularis*, were extracted the results given in Tables 2 and 3, and Fig. 1.

The author obtained the results given in Table 2 and Fig. 1. In

Table 2. Regression equations describing the growth at three temperature regimes

Temp (℃)	Regression equation	Determination coefficient (%)
≈20	$y = 0.3534 + 0.1613t + 0.0116t^2$	99.0
25	$y = 0.3937 + 0.1309t + 0.0237t^2$	99.6
30	$y = 0.3776 + 0.1872t + 0.0162t^2$	99.8

t : Nymphal instar.

Table 1. Measurement of the head widths of the three temperature regimes for the six developmental stages in *G. paludum insularis* in ㎜ (mean ± standard deviation)

Developmental stage[b]	Sample size	Temperature (℃)[a]		
		≈20	25	30
Instar 1	30	0.556 ± 0.040 aA	0.579 ± 0.03 bA	0.593 ± 0.01 cA
Instar 2	30	0.689 ± 0.057 aA	0.683 ± 0.01 bA	0.786 ± 0.02 cA
Instar 3	30	0.910 ± 0.057 aB	1.028 ± 0.03 bB	1.117 ± 0.07 cB
Instar 4	30	1.189 ± 0.060 aC	1.317 ± 0.05 bC	1.359 ± 0.03 cC
Instar 5	30	1.528 ± 0.050 aD	1.641 ± 0.05 bD	1.745 ± 0.07 cD
Adult	30	1.697 ± 0.050 aE	2.028 ± 0.06 bE	2.076 ± 0.06 cE

Means in a row followed by the same capital letters and means in a column followed by the same lowercase letters are not significantly different (P=0.05; Duncan's[1955] multiple range test).

[a] Temperature : F=10.77, F (df=2, 10)=4.10, P<0.01.

[b] Developmental stage : F=171.69, F (df=5, 10)=3.325, P<0.001.

Table 3. Analysis of growth pattern of the head width of *G. paludum insularis*

Temperature (℃)	Stage	GQ (mm)	QR (times)		E (mm)	ER (%)	GR (mm/t)
≈20	Instar 1	0.5263	1.000	1.000	0.0297	5.643	0.1845
	Instar 2	0.7224	1.372	1.372	-0.0334	-4.623	0.2077
	Instar 3	0.9417	1.789	1.303	-0.0317	-3.366	0.2309
	Instar 4	1.1842	2.250	1.257	0.0048	0.405	0.2541
	Instar 5	1.4499	2.754	1.224	0.0781	5.386	0.2773
	Adult	1.7388	3.303	1.199	-0.0418	-2.403	0.3005
25	Instar 1	0.5483	1.000	1.000	0.030	5.47	0.1783
	Instar 2	0.7503	1.368	1.368	-0.067	-8.92	0.2257
	Instar 3	0.9997	1.823	1.332	0.028	2.80	0.2731
	Instar 4	1.2965	2.364	1.296	0.020	1.54	0.3205
	Instar 5	1.6407	2.992	1.265	0.0003	0.01	0.3679
	Adult	2.0323	3.706	1.238	-0.004	-0.19	0.4153
30	Instar 1	0.5810	1.000	1.000	0.012	2.065	0.2196
	Instar 2	0.8168	1.405	1.405	-0.030	-3.672	0.2520
	Instar 3	1.0850	1.867	1.328	0.032	2.949	0.2844
	Instar 4	1.3856	2.385	1.277	-0.026	-1.876	0.3168
	Instar 5	1.7186	2.958	1.240	0.026	1.512	0.3492
	Adult	2.0840	3.586	1.212	-0.008	-0.383	0.3816

GQ : Growth quantity, QR : Ratio of growth quantity, E : Error, ER : Relative error, GR : Growth rate.

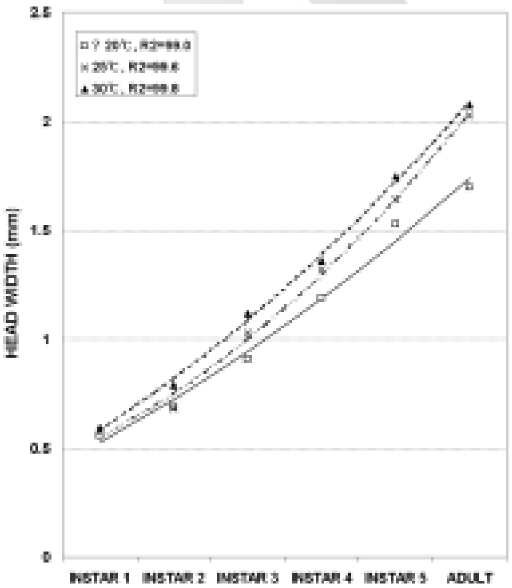

Fig. 1. The growth curves for the growth of the head width of *G. paludum* insularis.

≈20℃, the growth formula is the equation y = 0.3534 + 0.1613t + 0.0116t^2, curved somewhat concavely, but approached nearly to a straight line. The maximum relative error of above formula is 5.643%. In other words, the formula was finished off the growth within the limits of error of 5.643%. The maximum range of the relative error is 10.266%. The growth quantity is increased in length by 3.303 times, 0.5263 ㎜ of the first instar larva to 1.7388 ㎜ of the adult. In the ratio of growth quantity by each instar, that of the first instar larva (1.372 times) was the largest, whereas that of the fifth instar larva (1.199 times) was the smallest. That is, the ratio of growth quantity by each instar was decreased successively. The growth rate was increased 0.1845 ㎜/t of the first instar larva from 0.3005 ㎜/t of the adult.

In 25℃, the growth formula is the equation y = 0.3937 + 0.1309t + 0.0237t^2, curved somewhat concavely, but approached nearly to a straight line. The maximum relative error of above formula is 8.920%. In other words, the formula was finished off the growth within the limits of error of 8.920%. The maximum range of the relative error is 14.390%. The growth quantity is increased in length by 3.706 times, 0.5483 ㎜ of the first instar larva to 2.0323 ㎜ of the adult. In the ratio of growth quantity by each instar, that of the first instar larva (1.368 times) was the largest, whereas that of the fifth instar larva (1.238 times) was the smallest. That is, the ratio of growth quantity by each instar was decreased successively. The growth rate was increased 0.1783 ㎜/t of the first instar larva from 0.4153 ㎜/t of the adult.

In 30℃, the equation of the growth formula is $y = 0.3776 + 0.1872t + 0.0162t^2$, curved somewhat concavely, but approached nearly to a straight line. The maximum relative error of above formula is 3.672%. In other words, the formula was finished off the growth within the limits of error of 3.672%. The maximum range of the relative error is 6.614%. The growth quantity is increased in length by 3.586 times, 0.5810 ㎜ of the first instar larva to 2.0840 ㎜ of the adult. In each instar, the ratio of the growth quantity of the first instar larva (1.405 times) was the largest, whereas that of the fifth instar larva (1.212 times) was the smallest. Thus, the ratio of the growth quantity by each instar was decreased successively. The growth rate was increased 0.2196 ㎜/t of the first instar larva from 0.3816 ㎜/t of the adult.

Growth in animal body is always more or less cyclical, alternating the periods of comparative rest with periods of activity. But in no group is this so evident as in the insects, in which development is punctuated by a series of moults, each preceded by a period of active growth and followed by a period in which true growth may be entirely absent.

The control of form in the insects is mainly centered in the epidermis. The changes in form result from local changes in the intensity of epidermal cell division. Furthermore, the epidermis of the insect retains an embryonic character throughout post embryonic development. It can differentiate into new organs.

The law of growth results when the increase in size of a quantity is always proportional to that. This is illustrated by nature when the growth of organism is proportional to the size of that. This could also be called a "logarithmic rate" of growing because the percentage increase is always proportional to the magnitude at that instant. The author employed the quadratic equations for the interpretation of growth of the head width in *G. paludum insularis*. The general form, $y = a + bt + ct^2$, stands for the growth quantity as the function of time t in each instar, that is synthetical expression of metabolic system. In this equation, first, a can be positive number (greater than zero) or negative number (less than zero), it can never be zero. Second, b can also be a positive or negative number, but it can also be zero. Third, c can be a positive or negative number or zero. Therefore, the relationship between the growth quantity and time t in each instar can be expressed by the growth curve.

The growth formula was applies by Park and Lee (1971), Park and Son (1984) and so on. Park (1988) reported that effects of temperature on the development of the water strider, *G. paludum insularis*. Park (1988) reported that the rates of egg hatch and adult emergence were higher at 25 and 30℃ than at other temperatures. The survivorship curve of *G. paludum insularis* varied with temperature. At 25 and 30℃, the curve is concave. The development time was significantly decreased as the temperature increased (P< 0.01). Park *et al.* (1983) reported that influence of Cu(II) on the growth of Korea axolotl, *Hynobius leechii*. Robinson *et al* (1983) reported that the effects of body size and temperature on metabolic rate of organism.

Growth of head in the five species did not confirm to Dyar's law (which states a constant percentage increase in the head width in each moult) (Mukerji 1972). In this study, the growth of head width in the three temperature regimes did not confirm exactly to Dyar's law.

The ratio of growth quantity of 25℃ (3.706 times) was the largest, and 30℃ (3.586 times) and ≈20℃ (3.303 times) follow in that order. In the ratio of growth quantity by each instar, that of the first instar larva was the largest in all the regimes. It shows a tendency to decrease by the development of the instar. Park and Lee (1971) pointed out that the maximum ratio of growth quantity of antenna by each instar in *A. dallasi*, is in a young instar larva, but the minimum is in a advanced stage. And Park and Lee (1971) indicated that it is also decreased according to the development of the instars.

The growth rate of the first instar larva is the smallest in all the temperature regimes. It shows tendency to increase by the development of the instars. Park and Lee (1971) also summarized that only the growth rate of antenna in six variables shows a decrease pattern. The growth rate of all antennal segments showed a decrease pattern. However, the fourth segment shows the slowest, and the first, second and third segments follow in the written order.

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