KOREAN JOURNAL OF ZOOLOGY
Vol. 29, No. 3, pp. 201-207 (1986)

Respiration in the Adult of the Water Striders, *Gerris paludum insuralis* (Insecta, Hemiptera, Gerridae)

Sang Ock Park and Eun Young Joo*
(Department of Biology Education, Hyosung Women's University;
Daegu College of Oriental Medicine*)

소금쟁이 (*G. paludum insuralis*) 성체의 호흡

朴 商 玉·朱 恩 榮*
(효성여자대학교 생물교육학과, 대구한의과대학*)

(Received April 29, 1986)

요 약

소금쟁이 (*Gerris paludum insuralis*) 성체의 호흡률을 25°C, 30°C, 35°C 및 40°C에서 암·수별로 각각 1시간동안 매 5분간격으로 산소소비율을 측정하여 다음과 같은 결론을 얻었다. (1) 30°C에서는 시간경과에 따른 산소소비량의 변화가 다른 온도군에 비해 매우 적었으며, 첫 5분간과 마지막 5분간의 양이 거의 비슷하여 생활적온으로 판단되며, 그 외의 온도에서는 시간경과에 따라 단위시간당 산소소비량은 주기적인 감소상을 나타내었다. (2) 산소소비율은 대체로 수컷이 암컷보다 많았다. (3) 산소소비량은 25°C, 30°C, 35°C 및 40°C에서 각각 0.42, 0.49, 0.79 및 1.11 μl/mg/hr로서 온도가 높아짐에 따라 증가하였다. (4) Q_{10}은 수컷에서는 25°C~35°C의 온도간격에서 높았고, 암컷은 30°C~40°C의 온도간격에서 높았다. 평균 Q_{10}은 2.12였다. (5) 생체량 10 mg, 건조중량 5 mg이상에서는 체중이 높을수록 산소소비량은 감소하였다. (6) 호흡정지고온과 호흡정지저온은 각각 48.31°C와 17.68°C였다. (7) 30°C를 제외한 세 온도군에서 호흡이 정지되는 시간은 약 110분 후로 추정되었다.

INTRODUCTION

Respiratory metabolism is considered as a self regulating system, where oxygen consumption adjusts itself to the demand by endergonic processes necessary to the survival and development of the animal (Bosquet, 1976). The rate of respiration in *Drosophila* is important physiological properties which may vary with sex, strain, temperature, and humidity (Keister and Buck, 1964). The metabolic differences existed among melanistic strains of *Drosophila melanogaster*, the light forms having a higher respiratory rate at intermediate temperature (Vernberg and Merinoy, 1957) (Vide Tonzetich *et al.*, 1976).

Numerous works deal with the pattern of respiratory metabolism in animals; occurring variations are generally interpreted as being manifestations of physiological events such as growth and morphogenesis (Janda, 1961; Webb, 1969; Fourche, 1969; Janda and Stresovzka, 1971; Edson and Vinson, 1976), initiation of imaginal development (Schneidermann and Williams, 1953), moulting (Fourche, 1967), diapause (Denlinger *et al.*, 1972; Hayes *et al*, 1972; Ellingsen, 1978) ovogenesis (Slama, 1964; Fourche and Ambrosioni, 1969), temperature and humidity (Keister and Buck, 1964; Peakin *et al.*, 1985), starvation (Bosquet, 1976) and anaerobiosis (Zachariassen and Pasche, 1976).

But these papers treated mites, larvae and pupae of holometabolous insects. No information on the respiration of hemimetabolous insects has been found in the literature.

The authors attempted to investigate the oxygen consumption rate, the changes in the physiological state of sexuals of the water striders, *Gerris paludum insuralis* which could be used as the biological indicator species for water pollution in the collection of data on respiration of hemimetabolous insects.

MATERIALS AND METHODS

Adult *Gerris paludum insuralis* were collected from the pond in the campus of Hyosung Women's University, Taegu, Korea between July and September 1985. All samples were tested within 24 hours after collecting.

The respiration was measured at 25, 30, 35 and 40°C in Warburg respirometers (V 166, B. Braun Melsungen). The adults were used singly for respiratory measurements with sex distinction. The adults were allowed to acclimate in the respirometer chambers for 1 hour before beginning manometric measurements. Readings of manometric measurements were made at 5 min intervals for 1 hour. The reaction flasks were shaken 50 times per minute during the course of experiments. 0.21 ml of 20% KOH solution was placed in the center well of the flasks, which was sufficient to absorb the CO_2 released. Approximately $2cm^2$ of folded filter paper was put in the center well to provide a greater absorption area. Temperature of the floating vessel was constant within ± 0.01°C. The vessels were placed in the water-bath for 10 min to obtain temperature equilibrium.

After determining the respiratory rate, the adult was taken out of vessels and immediately weighed to determine the fresh weight of the insects with an electro micro-balance (Mettler H 54 AR). They were then dried at 60°C in an oven for 24 hours and weighed again to give the dry weight.

The data on insects that had been wetted by the KOH were discarded. The volume of oxygen consumption was calculated by the Warburg Standard Method. Results were expressed as microliters per milligram weight for 1 hour, μl/mg/h. A regression line and curve relating oxygen consumption rate at each temperature was fitted to the data by using the x-intercept method.

RESULTS AND DISCUSSION

Oxygen consumption rate

The oxygen consumption rate of adult was individually measured at the four temperature groups of 25, 30, 35 and 40°C. Table 1 shows the oxygen consumption rate (QO_2) at each temperature. The QO_2 of males at temperatures of 30, 35 and 40°C were 1.55, 2.13 and 2.80 times larger than that of 25°C (0.40 μl/mg/hr) respectively. The QO_2 of females in 30°C was 0.84 times smaller than that of 25°C, whereas those of 35 and 40°C were 1.57 and 2.50 times larger than that of 25°C respectively. The oxygen consumption rate of male was generally higher than that of females at three temperature groups except 25°C. There was significant difference in the QO_2 between male and female ($p<0.01$). The rate of oxygen consumption varied significantly with change in temperature ($p<0.01$).

The general response of the males and females to temperature changes were demonstrated in the Q_{10}'s calculated for each set of measurement. The females showed a higher response in the higher temperature interval (30~40°C) than the lower temperature interval (25~35°C), but the males showed a higher response in the lower temperature interval. Overall, the water striders showed a higher response in the higher temperature interval. Nielsen *et al.* (1985) reported that the Q_{10} of male ant changed but in the opposite sense to that of female. The problem on the differences of the respiratory rate in the sexuals of the water

Table 1. Oxygen consumption rate of *G. paludum insuralis* at each temperature (Mean±Standard deviation). Top: male, Intermediate: female, Last: overall

T(°C)	Respiration rate		Body weight(mg)		Water content(%)	No.	Q_{10}
	μl O_2/mg fw/hr	μl O_2/ind/hr	Fresh weight	Dry weight			
25	0.40±0.15	11.01±3.05	29.02±6.51	12.80±5.39	55.89	7	
30	0.62±0.20	15.17±4.57	24.97±3.68	12.67±1.68	49.26	14	2.13
35	0.85±0.28	19.89±3.47	25.27±6.45	14.24±2.38	43.61	13	1.81
40	1.12±0.19	25.56±4.11	23.23±4.28	11.57±3.29	50.19	12	
25	0.44±0.13	17.06±5.15	39.70±5.98	15.30±4.82	61.46	13	
30	0.37±0.10	12.63±3.52	34.56±5.41	16.52±2.37	52.20	15	1.57
35	0.69±0.21	29.24±7.86	43.02±2.79	20.02±1.92	53.46	7	2.97
40	1.10±0.18	29.97±7.39	27.72±8.23	12.15±5.98	56.17	9	
25	0.42±0.14	14.94±5.37	35.97±8.00	14.43±5.17	59.88	20	
30	0.49±0.20	13.85±4.25	29.93±6.68	14.66±2.82	51.02	29	1.88
35	0.79±0.27	23.16±7.02	31.48±10.07	16.27±3.54	48.35	20	2.27
40	1.11±0.19	27.45±6.15	25.15±6.67	11.82±4.65	53.04	21	

T: Temperature, fw: Fresh weight, ind: Individual, No.: Number of assays

striders will be examined more in the future.

Fig. 1 represents the different patterns of the oxygen consumption rates to temperature. The effect of temperature on oxygen consumption rate was expressed by the equation for male was $y=-0.2935+0.0153x+0.0005x^2$ ($R^2=0.99$), female $y=4.0750-0.2660x+0.0048x^2$ ($R^2=0.98$) and overall $y=1.7244-0.1151x+0.0025x^2$ ($R^2=0.99$). The pattern of oxygen consumption rate in male shows a straight line, while that of female shows a concave type. Thus overall, the oxygen consumption rate of a water striders was increased according to the increase of the temperature. After testing for 1 hour, all of the individuals moved briskly at the three temperature groups of 25, 30 and 35°C. But at 40°C, all of the individuals overbalanced itself, and half of them excreted ruddy body fluid at the anus.

Relationships between body weight and respiratory rate

Fig. 2 illustrates the relationships between body weight and respiratory rate in constant temperature. As in the figure, the respiratory rate was decreased as the fresh weight was increased to 10 mg or more. There was an initial rapid rise in the respiration rate at the start as the dry weight increases to 4.5 mg, followed by a steady decline as the weight tended to be a maximum at the temperature of 10, 20 and 30°C, but no significant differences were found in the slopes of either the rising or falling phase of the regression line (Nielsen *et al*, 1985). The respiration rate of a water striders, *Gerris paludum insuralis* was also decreased as the dry weight was increases form 5 mg to a maximum.

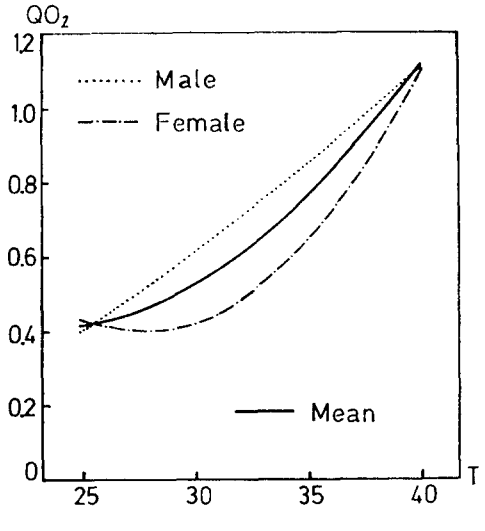

Fig. 1. The relationship between the oxygen consumption rate and temperature for male and female. M: T: Temperature in (°C), QO_2: O_2 consumption rate (μl/mg/hr)

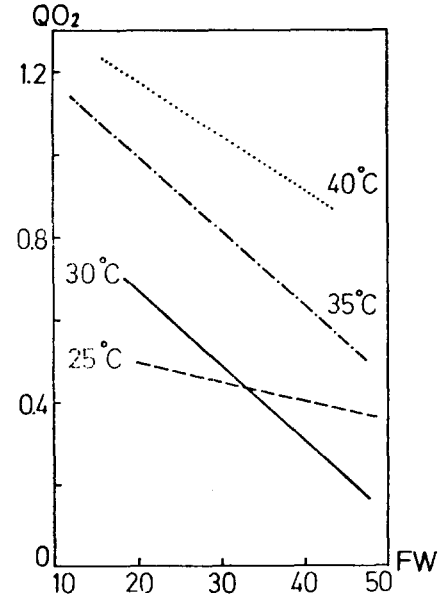

Fig. 2. The relationship between the fresh weight and respiratory rate for constant temperature. QO_2: O_2 Consumption rate (μl/mg/hr) FW: Fresh weight (mg)

Hereafter, it will be examined more and more about this problem.

Change of oxygen uptake rate with the lapse of time

Table 2 and Fig. 3 showed the change patterns of oxygen uptake rate for each temperature during 1 hour. The pattern of oxygen consumption rate for 25, 35 and 40°C was diverged from the normal standard of 30°C. At 30°C, oxygen uptake rate for the first 5 min (0.0481 μl/mg) was similar to that of the last 5 min (0.0442 μl/mg), but the rates of the other three temperature groups were decreased periodically as time goes on. This cyclic decrease of oxygen consumption rate in three temperature groups is regarded as a means to a restoration of unfavourable environment.

Denlinger *et al.* (1972) reported infradian cycles of oxygen consumption in individual diapausing pupae of *Sarcophaga* spp. at a optimum temperature of life. There was no information on a cyclic change of oxygen uptake rate with the lapse of time in individual insect at a various range of temperature. The authors intended to infer the ceasing time of breathing by using the x-intercept method. By inference, the oxygen consumption rate for three temperature groups of 25, 35 and 40°C except 30°C was decreased to zero as the time of ca. 110 minutes goes by (Fig. 4).

Upper and lower temperature thresholds for respiration

The present authors attempted to analyze the upper and lower temperature thresholds for respiration in *G. paludum insuralis* by using the x-intercept method, $y=a+bt$. The temperature threshold for respiration inducing death means the value of t when $y=0$, that is $\theta=a/b$. In analysis of a upper and lower temperature threshold for respiration, the value of y means the respiratory velocity ($1/QO_2$) and respiratory rate (QO_2) respectively, being determined by the temperature, t. The two covstants a and b can be calculated by the usual method of least square. The upper and lower temperature thresholds for their

Table 2. Oxygen consumption rate during 1 hr in various temperature (unit: μl/mg)

Time(min) \ Temperature	25°C	30°C	35°C	40°C
5	0.0394	0.0481	0.0899	0.1459
10	0.0312	0.0426	0.0759	0.1056
15	0.0384	0.0356	0.0714	0.1020
20	0.0684	0.0360	0.0697	0.0906
25	0.0459	0.0307	0 0646	0.0760
30	0.0335	0.0428	0.0647	0.0934
35	0.0329	0.0302	0.0573	0.1039
40	0.0269	0.0324	0.0423	0.0888
45	0.0313	0.0406	0.0483	0.0731
50	0.0182	0.0393	0.0485	0.0697
55	0.0263	0.0398	0.0519	0.0557
60	0.0223	0.0442	0.0506	0.0861

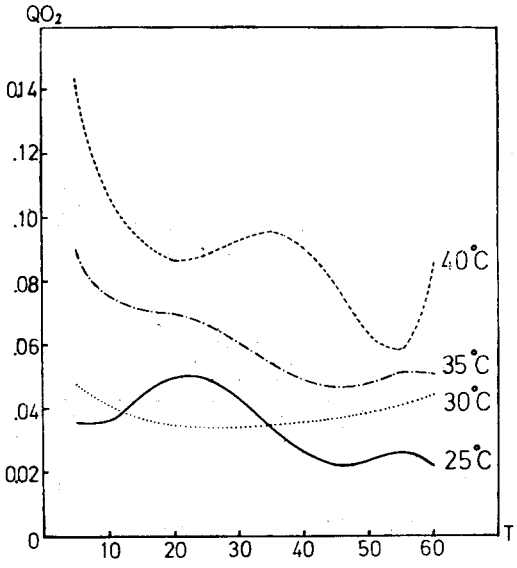

Fig. 3. Change pattern of oxygen uptake rate during 1 hr at four temperature groups of 25°C to 40°C in adult of *G. paludum insuralis*. QO_2: O_2 uptake rate (μl/mg/5min) T: Time in minute

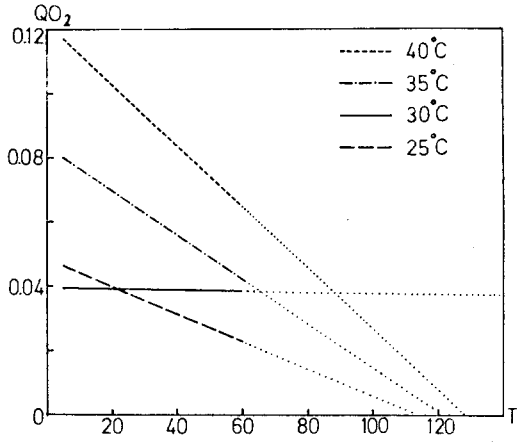

Fig. 4. Linear regression for inference of the ceasing time of breathing. QO_2: O_2 uptake rate (μl/mg/hr) T: Time in minute

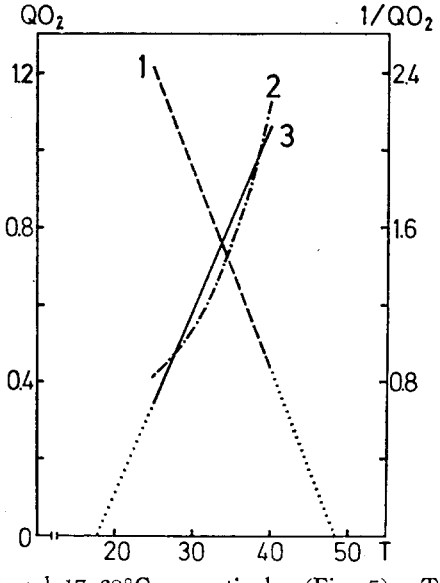

Fig. 5. Inference of the upper and lower temperature threshold for respiration in *G. paludum insuralis*. QO_2: O_2 uptake rate (μl/mg/hr), $1/QO_2$: respiratory velocity 1: Linear regression for inference of the upper temperature threshold. 2: Change pattern of mean respiratory rate 3: Linear regression for inference of the lower temperature threshold T: Temperature in °C

respiration analyzed in this way were 48.31°C and 17.68°C respectively (Fig. 5). The mature males had a very high Q_{10} at the maximum degree of 20°C but thereafter responded quite moderately to temperature changes. It may be argued that the temperature of 20°C represents a threshold level for their mating activity (Nielsen *et al.*, 1985).

ABSTRACT

The authors attempted to investigate the oxygen consumption rate of sexuals in the water-

striders, *Gerris paludum insuralis*, at four temperature groups of 25, 30, 35 and 40°C in a series of studies on respiration of a hemimetabolous insects. The results are summarised as follows: (1) At 30°C, the change of oxygen consumption rate according to the lapse of time was small in comparison with the other three temperature groups which shows a cyclic decreasing pattern. The rate during initial and final 5 minutes was much alike. Thereupon, the optimum temperature was regarded as 30°C. (2) The oxygen consumption rate of male was higher than that of female. (3) The oxygen consumption rates at 25, 30, 35 and 40°C were 0.42, 0.49, 0.79 and 1.11 μl/mg/h respectively. That is, the rate was increased as the temperature was increased. (4) The Q_{10} of male showed a high value in the lower temperature interval (25~35°C), but the female showed a high value in the higher temperature interval (30~40°C). The mean Q_{10} was 2.12. (5) The respiratory rate was decreased as the body weight was increased in the above fresh weight of 10mg and dry weight 5 mg. (6) The upper temperature threshold for respiration was 48.31°C and the lower temperature threshold was 17.68°C. (7) The ceasing time of breathing at the other three temperature groups except 30°C was infered to be about 110 minutes after the start of experiment.

REFERENCES

Bosquet, G., 1976. Glycine incorporation during starvation in *Bombyx mori* relation to respiratory metabolism. *J. Insect Physiol.* 22:541-545.

Denlinger, D.L., J.H. Willis, and G. Fraenkel, 1972. Rates and cycles of oxygen consumption during pupal diapause in *Sarcophaga* fresh flies. *J. Insect Physiol.* **18**:871-882.

Edson, K.M. and S.B. Vinson, 1976. The function of the anal vesicle in respiration and excretion in the braconid wasp, *Microplitis croceipes*. *J. Insect Physiol.* 22:1037-1043.

Ellingsen, I.J., 1978. Oxygen consumption in active and quiescent protonymphs of the American house-dust mite. *J. Insect Physiol.* **24**:13-16.

Hayes, D.K., J. Horton, M.S. Schechter, and F. Halberg, 1972. Rhythm of oxygen uptake in diapausing larvae of the codling moth at several temperatures. *Ann. Entomol. Soc. Am.* **65**(1):93-96.

Nielsen, M.G., N. Skyberg and G. Peakin, 1985. Respiration in the sexuals of the ant *Lasius flavus*. *Physiol. Entomol.* **10**:199:204.

Peakin, G., M.G. Nielsen, N. Skyberg and J. Pedersen, 1985. Respiration in the larvae of the ants *Myrmica scabrinodis* and *Lasius flavus*. *Physiol. Entomol.* **10**:205-214.

Tonzetich, J., C.L. Ward, and E. Denny, 1976. Effects of temperature and humidity on hydration and respiration in four strains of *Drosophila*. *J. Insect Physiol.* 22: 107-113.

Webb, N.R., 1969. The respiratory metabolism of *Nothrus silvestris* Nicolet (Acari). *Oikos*, **20**:294-299.

Zachariassen, K.E. and A. Pasche, 1976. Effect of anaerobiosis on the adult cerambycid beetle, *Rhagium inquisitor* L. *J. Insect Physiol.* 2:1365-1368.