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# EFFECT OF TEMPERATURE ON THE WING LENGTH–BODY WEIGHT RELATIONSHIP IN *ANOPHELES QUADRIMACULATUS*

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ABSTRACT. The effect of temperature on the relationship between wing length and body weight in a cohort of *Anopheles quadrimaculatus* was analyzed in a laboratory experiment. Mosquitoes reared at 23°C were heavier and had longer wings than did those reared at 28°C. In addition, even after differences in body weight were removed statistically, mosquitoes raised at 23°C had longer wings than did those at 28°C. The concordance of these results with those of a previous photoperiod study suggests that temperature and photoperiod experienced during development have some similar effects on the morphology of *An. quadrimaculatus.*

Members of *Anopheles quadrimaculatus* (probably species A on the basis of habitat and region; Kaiser et al. [1988]) reared under different photoperiods develop different body dimensions. Wings are longer and body weights are heavier in individuals reared at a short photoperiod of 8 h light : 16 h dark than in those reared at a long photoperiod of 16 h light : 8 h dark (Lanciani 1992). Wings are longer and body weights are heavier also in mosquitoes reared at low temperatures than in those reared at high temperatures (Hosoi 1954, van den Heuvel 1963, Nayar 1968), suggesting that photoperiod and temperature have similar effects on the morphology of developing mosquitoes.

In addition, different developmental photoperiods change the allometric relationship between wing length and body weight in *An. quadrimaculatus* (Lanciani 1992). Short-photoperiod individuals have longer wings than do long-photoperiod individuals of the same body weight (Lanciani 1992, after reanalyzing data with wing length as the dependent variable and body weight as the independent variable).

In this report, we tested the possibility that different temperatures, like different photoperiods, change the allometric relationship between wing length and body weight in *An. quadrimaculatus.* Mosquitoes analyzed in the present study were from the same population used previously to test the effects of photoperiod on the relationship between wing length and body weight. Different developmental temperatures are known to change the allometric relationship between wing length and body weight in other mosquitoes (e.g., species of *Aedes* [van den Heuvel 1963, Siegel et al. 1994]). Specifically, individuals of *Aedes aegypti* (Linn.) reared under low temperatures have disproportionately longer wings than do those reared under high temperatures (van den Heuvel 1963).

Blood-engorged female *An. quadrimaculatus* (probably species A) were collected from a daytime resting site on the shore of Lake Alice, Gainesville, FL, on September 10, 1994. Mosquitoes were held separately in plastic vials (3 cm diam × 7 cm height) with a few ml of water, the vials were put in covered plastic boxes containing moistened paper towels, and the boxes were housed in a constant temperature chamber set at 28°C and a 12 h light–dark cycle. The first clutch of eggs laid by a female was used in the rearing experiment. Half of the eggs from this clutch were placed into a constant-temperature chamber set at 23°C and the other half into a constant-temperature chamber set at 28°C. The photoperiod was the same in both chambers, 12 h light and 12 h dark. Eggs at each temperature were held within a floating paper ring in 500 ml of tap water in a white enamel pan. On the day after oviposition, 0.05 g of a 2:1 mixture of baby-fish food and brewer's yeast was added to each pan. Two days later, 2 groups of approximately 40 larvae of similar sizes were selected from each pan, and each group was put in a separate pan after 500 ml of tap water and 0.06 g of food had been added. Thus, the experiment consisted of 2 groups of 40 larvae at each temperature. Larvae were transferred each day to clean pans containing 500 ml of fresh tap water and were fed according to this schedule on successive days: 0.06, 0.07, and then 0.09 g of food per pan until pupation of all larvae in a pan. The pans were covered with clear plastic sheets to reduce evaporation. As pupae appeared, they were removed and placed in screen-covered vials in the same constant-temperature chamber in which they developed. Adults were frozen between 4 and 16 h after emergence and were later dried for 2 days at 60°C before measurement. Dried mosquitoes were weighed individually with a Cahn electrobalance. Then one wing (usually the right wing) was removed, immersed in alcohol to remove wrinkles, and measured with an ocular microm-

Table 1. Wing lengths (WL in mm) and dry weights (wt in mg) of *Anopheles quadrimaculatus* reared at 23°C and 28°C.

| Temperature | Sex | Mean WL ± SE | Mean wt ± SE | *n* |
|---|---|---|---|---|
| 23°C | Male | 3.975 ± 0.010 | 0.819 ± 0.009 | 40 |
| | Female | 4.535 ± 0.016 | 1.088 ± 0.012 | 39 |
| 28°C | Male | 3.636 ± 0.014 | 0.680 ± 0.007 | 47 |
| | Female | 4.079 ± 0.021 | 0.889 ± 0.016 | 28 |

eter from the axillary incision to the apex, excluding the scales.

Analysis of variance was used to test wing-length and body-weight differences within sexes at the 2 temperatures and between sexes at the same temperature. Covariance analysis was used to determine the relationship between wing length and body weight of low- and high-temperature mosquitoes of each sex. The variables wing length (the dependent variable) and body weight (the independent variable) were logarithmically transformed to improve the fit to the linear covariance model.

Wings of males were significantly shorter than those of females at the same temperature ($P$ = 0.0001), and wings of high-temperature individuals were significantly shorter than those of low-temperature individuals of the same sex ($P$ = 0.0001) (Table 1). Likewise, body weights of males were significantly lighter than those of females at the same temperature ($P$ = 0.0001), and body weights of high-temperature individuals were significantly lighter than those of low-temperature individuals of the same sex ($P$ = 0.0001) (Table 1).

Covariance analysis showed that wing length was significantly affected by body weight ($P$ = 0.0001), temperature ($P$ = 0.0002), sex ($P$ = 0.0001), a temperature–sex interaction ($P$ = 0.006), a temperature–body weight interaction ($P$ = 0.01), a sex–body weight interaction ($P$ = 0.03), and a temperature–sex–body weight interaction ($P$ = 0.04). This model accounted for 96% of the variation in wing length.

Table 2. Parameters of regression equations predicting log (base 10) wing length (mm) from log (base 10) dry body weight (mg) in male and female *Anopheles quadrimaculatus* reared at 23°C and 28°C. The equations are of the form $Y = a + bX$, in which $Y$ is log wing length, $a$ is the $Y$ intercept, $b$ is the slope, and $X$ is log dry body weight. For example, log wing length of 23°C males is equal to 0.602 + 0.036 log dry body weight.

| Temperature | Sex | Intercept | Slope |
|---|---|---|---|
| 23°C | Male | 0.602 | 0.036 |
| | Female | 0.649 | 0.205 |
| 28°C | Male | 0.598 | 0.224 |
| | Female | 0.622 | 0.224 |

The significant interactions mean that the regression lines relating wing length to body weight have different slopes for each sex and temperature (Table 2). These slopes, together with the listed intercepts, define equations that predict wing length from body weight (Table 2). Using these equations to predict wing lengths of mosquitoes with the minimum, mean, and maximum body weights observed within each sex shows that low-temperature individuals have longer wings than do high-temperature individuals of the same body weight and sex: in 23°C vs. 28°C males—3.929 vs. 3.526 mm (at the minimum weight of 0.592 mg); 3.961 vs. 3.706 mm (at the mean weight of 0.740 mg); 3.994 vs. 3.904 mm (at the maximum weight of 0.933 mg) and in 23°C vs. 28°C females—4.179 vs. 3.905 mm (at the minimum weight of 0.729 mg); 4.454 vs. 4.187 mm (at the mean weight of 0.995 mg); 4.670 vs. 4.409 mm (at the maximum weight of 1.250 mg).

Thus, changes in the allometric relationship between wing length and body weight produced by different rearing temperatures are qualitatively like changes observed in the allometric relationship between wing length and body weight produced by different rearing photoperiods. At least in the single cohort of sibling mosquitoes analyzed, temperature had a morphological effect similar to a previously observed morphological effect induced by photoperiod on developing *An. quadrimaculatus*.

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