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Further Evidence of Male Trimorphism in the Horned Beetle *Trypoxylus dichotomus septentrionalis* (Coleoptera, Scarabaeidae)

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Abstract Larvae of the horned beetle *Trypoxylus dichotomus septentrionalis* are reared under an experimental condition, and the horn length and body length of male adults obtained from those larvae are measured. Analysis by a moving-average method indicates trimodal horn-size distribution, where medium-sized males are the most abundant. Body–horn allometry also exhibits three discontinuous regression lines corresponding to three male morphs, namely, small, medium and large males. The present and previous studies strongly suggest existence of male horn trimorphism in this beetle.

Introduction

Males of *Trypoxylus dichotomus septentrionalis* (Kôno) show morphological dimorphism and are divided into two morphs with respect to horn size, minors and majors (Siva-Jothy, 1987; Iguchi, 1998). Therefore, frequency distribution of male horn sizes in this beetle is usually bimodal. However, Siva-Jothy (1987) pointed out the possibility of trimodality of male horn sizes in this beetle. Later, my study (Iguchi, 2000) also showed this possibility on the basis of body–horn allometry, but the sample size (n=30) was small. Therefore, it is still unclear whether males of this beetle show morphological trimorphism or not. In the present study, I used more males to examine horn-size distribution and body–horn allometry. Here I discuss male trimorphism in this beetle in detail. This paper is dedicated to Professor Yasuaki Watanabe in commemoration of his retirement from Tokyo University of Agriculture.

Materials and Methods

For this study, 200 last instar larvae of *Trypoxylus dichotomus* were collected from the soil (10 m×10 m×0.5 m deep) near a forest of assorted trees in the western part of Tatsuno-machi, Kamiina-gun, Nagano Prefecture on 5 May 2001. The soil was dark, soft, moist humus that contained many chips of decayed wood. The larvae were put in 5 plastic boxes (40 larvae in each box) of the same size (37 cm×70 cm×30 cm high) with the soil (28 cm deep) in which they had lived. Each box was covered with a plastic board and placed outdoors in Okaya City, Nagano Prefecture. Throughout this study, no more humus or soil was added, but water was sprinkled to keep the soil moist.

In this rearing experiment, 77 males and 84 females emerged in July and August 2001. For the present study, however, only the males were used. For each male, the length of the head horn and the length of the body excluding the horns were measured to 0.1 mm with a slide caliper.

To analyze the polymodal frequency distribution of horn sizes, a moving-average method was used. This method was proposed by TAYLOR (1965) and used by SIVA-JOTHY (1987) to examine the shape of horn-size distribution in this beetle. In the present study, each moving average of horn-size frequencies was calculated over three successive classes of horn sizes. For example, the original frequencies of the three horn-size classes, 4.0–4.5 mm, 4.5–5.0 mm and 5.0–5.5 mm, were 1, 1 and 6, respectively. Then, the moving average of the middle class (4.5–5.0 mm) was calculated as $(1+1+6)/3=2.7$. In this way, the moving average of every class was calculated. If analysis by the moving-average method suggested the existence of a trimodal distribution in horn size, three regression lines were fit to the three separate male groups, that is, small, medium and large males.

Results and Discussion

The moving-average distribution of horn sizes was clearly trimodal (Fig. 1), as suggested by SIVA-JOTHY (1987). In my previous study (IGUCHI, 2000), trimodality of horn sizes was not clear probably because of the small sample size. SIVA-JOTHY (1987) also threw doubt on the existence of horn trimorphism. However, the present study showed trimodality of horn sizes more clearly than both my previous study (IGUCHI, 2000) and SIVA-JOTHY (1987). This may be due to the fact that the present sample size ($n=77$) was larger than my previous sample size ($n=30$) and SIVA-JOTHY's sample size ($n=67$).

SIVA-JOTHY (1987) did not show the mean horn size. Estimated from figure 3 in his paper, however, it was approximately 23.51 mm. On the other hand, it was 8.12 mm in the present study. The mean horn size was significantly smaller in the present study than in SIVA-JOTHY (1987) (Mann–Whitney U-test, $U=4995.5$, $P<0.00001$). As shown in Table 1, this is due to the fact that relative frequencies of small and medium males were higher in the present study than in SIVA-JOTHY (1987). It was also noted in Table 1 that medium males were the most abundant in the present study. If males showed horn dimorphism, relative frequency of medium males would have remained low. However, the relative frequency of medium males was the highest in the present study. This suggests the trimodality of horn sizes.

On the basis of body–horn allometry (Fig. 2), the males were divided into three groups, that is, small males (body length<33.5 mm, $n=34$), medium males (33.5

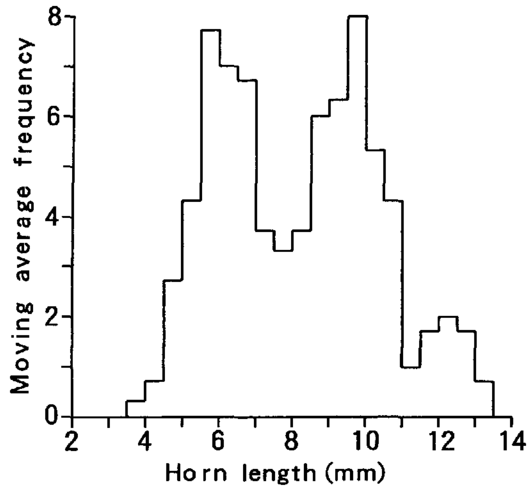

Fig. 1. Moving-average distribution of horn sizes for 77 males. Each moving-average frequency was calculated over three successive classes of horn sizes.

Table 1. Relative frequency (%) of three male morphs, namely, small, medium and large males in this study and SIVA-JOTHY (1987). The sample size indicates the number of males dealt with in each study.

	Small	Medium	Large	Sample size
This study	45	47	8	77
SIVA-JOTHY (1987)	18	10	72	67

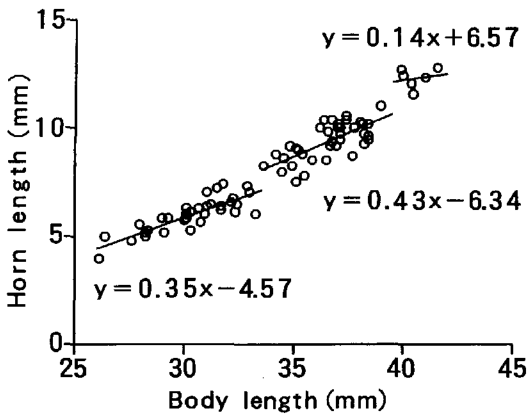

Fig. 2. Body–horn allometry for 77 males. The males were divided into three groups, namely, small males (body length<33.5 mm, n=34), medium males (33.5 mm≦body length<39.5 mm, n=37), and large males (39.5 mm≦body length, n=6).

mm≦body length<39.5 mm, n=37), and large males (39.5 mm≦body length, n=6). The regression lines for small and medium males did not differ significantly in slope (t=1.010, df=67, P>0.3), but they were almost parallel (t=3.891, df=68, P<0.001). Similarly, the regression lines for medium and large males did not differ significantly in slope (t=0.6710, df=39, P>0.5), but they were almost parallel (t=3.172, df=40, P<0.005). This result means that these three regression lines are discontinuous. In some dimorphic beetles, body–horn allometry is expressed as a sigmoidal curve (*e.g.*, EBERHARD, 1987; RASMUSSEN, 1994; EMLEN, 1996). In the present study, however, body–horn allometry was expressed as three discontinuous lines rather than a sigmoidal curve. Therefore, the body–horn allometry also strongly suggests the existence of male trimorphism in this beetle.

References

EBERHARD, W. G., 1987. Use of horns in fights by the dimorphic males of *Ageopsis nigricollis* (Coleoptera, Scarabeidae, Dynastinae). *J. Kans. ent. Soc.*, **60**: 504–509.

EMLEN, D. J., 1996. Artificial selection on horn length – body size allometry in the horned beetle *Onthophagus acuminatus* (Coleoptera: Scarabaeidae). *Evolution*, **50**: 1219–1230.

IGUCHI, Y., 1998. Horn dimorphism of *Allomyrina dichotoma septentrionalis* (Coleoptera: Scarabaeidae) affected by larval nutrition. *Ann. ent. Soc. Am.*, **91**: 845–847.

——— 2000. Male trimorphism in the horned beetle *Allomyrina dichotoma septentrionalis* (Coleoptera: Scarabaeidae). *Kogane, Tokyo*, **1**: 21–23.

RASMUSSEN, J. L., 1994. The influence of horn and body size on the reproductive behavior of the horned rainbow scarab beetle *Phanaeus difformis* (Coleoptera: Scarabaeidae). *J. Ins. Behav.*, **7**: 67–82.

SIVA-JOTHY, M. T., 1987. Mate securing tactics and the cost of fighting in the Japanese horned beetle, *Allomyrina dichotoma* L. (Scarabaeidae). *J. Ethol.*, **5**: 165–172.

TAYLOR, B. J. R., 1965. The analysis of polymodal frequency distributions. *J. Anim. Ecol.*, **34**: 445–452.