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Genetic Mode of Flight Muscle Dimorphism in a Scarabaeid, *Heptophylla picea* MOTSCHULSKY^{1,2}

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In certain groups of insects, species exhibit polymorphisms that affect their flight ability, the

most obvious examples being the variations in wing length and flight muscle development (HARRISON, 1980). Wing polymorphisms in insects are subject to genetic and environmental control (HARRISON, 1980; ROFF, 1986). JACKSON (1933) conducted a breeding experiment on the genetic control of the flight muscle polymorphism of a weevil, *Sitona hispidula*, and concluded that it may be caused by unfavorable conditions, such as food shortage during ontogenic development, rather than by genetic factors. However, other studies suggested that the wing form of alary poly(di)morphic coleopteran species is often determined genetically (JACKSON, 1928; HSIAO and HSIAO, 1985; AUKEMA, 1990; etc.), and many cases show that it is a simple Mendelian trait with brachyptery dominant to macroptery.

In a chafer, *Heptophylla picea* MOTSCHULSKY, all male adults have well-developed indirect flight muscles, whereas female adults exhibit flight muscle dimorphism (TADA et al., 1991). In this species, the intermediate morph in flight muscles has never been found, and the muscleless morph does not have flight muscles just after adult eclosion. This suggests that the development of the flight

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muscle is controlled genetically. In the present study, therefore, we tried to determine the genetic mode of flight muscle dimorphism in *H. picea*.

MATERIALS AND METHODS

In the female adults of *H. picea*, the proportion of female adults without flight muscles varies drastically throughout Japan (HONMA, 1990). In Naganuma, Hokkaido Prefecture, all female adults collected from 1990 to 1992 (1,016 specimens) had flight muscles, whereas in Kanaya, Shizuoka Prefecture, only one in 488 female adults had the muscles (TADA et al., unpublished). Thus, the individuals from these two localities were used as nearly pure line materials for single-cross experiments.

Third instar larvae were collected between late April and early May of 1991 from a *Locicera caerulea* (a kind of berry) field in Naganuma and from a tea field in Kanaya. Each larva was kept in a photo film case (3.0 cm dia. $\times$ 5.0 cm ht.) with some peat moss as medium and a piece of carrot (from 1,000 mm³ to 3,000 mm³) as food. These larvae were reared at room temperature, 15°C to 25°C, in the dark until adult eclosion. The food and peat moss was renewed weekly.

The following crosses were set up: Naganuma females $\times$ Naganuma males, Kanaya females $\times$ Kanaya males, Naganuma females $\times$ Kanaya males, and Kanaya females $\times$ Naganuma males (40 to 60 crosses for each crossing). Each pair was reared in a plastic cup (upper and lower diameter, 8.0 cm and 6.5 cm; ht., 4.0 cm) with some humid sand and leaves of white clover (*Trifolium repens*) as food. All pairs were kept at room temperatures ranging from 15°C to 25°C under natural day length conditions. The clover leaves were provided on demand. Eggs laid were collected, and the larvae

hatched from them were reared individually on carrot until adult eclosion at 18°C under in darkness (F₁ generation). All progeny from each of the four types of crosses were crossed inter se. Each pair was reared in the same plastic cup with white clover at 25°C under 16L-8D. Eggs laid were collected and the hatched larvae reared individually until the adult stage (F₂ generation).

All adults from each generation were kept in 70% ethanol and were monitored for their flight muscle development (TADA et al., 1991).

RESULTS AND DISCUSSION

The results of a crossing experiment of *H. picea* are shown in Table 1. The crosses of Naganuma $\times$ Naganuma produced only female offspring with flight muscles, whereas other crosses produced only female offspring without muscles. In F₁ by F₁ crosses, all the female offspring of Naganuma $\times$ Naganuma had flight muscles. Naganuma $\times$ Kanaya and Kanaya $\times$ Naganuma crosses produced female offspring in a 1:3 ratio of muscled females to muscleless females. All the female offspring from the crosses of Kanaya $\times$ Kanaya had no flight muscles. All F₁ and F₂ male offspring had flight muscles.

Some researchers have reported that extrinsic factors such as limited food supply, low temperatures and extremely long- or short-day conditions tend to suppress the development of flight muscles in Coleoptera (JACKSON, 1933; VAN SCHAIJCK ZILLESSEN and BRUNSTING, 1984). However, the present study showed that flight muscle form of *H. picea* is a genetic trait as reported in the wing form (ROFF, 1986).

Previous studies on some coleopteran species have shown that the wing form is a simple Mendelian trait with brachyptery dominant to macroptery

Table 1. Results of a crossing experiment of *Heptophylla picea*

Parents ^a	F ₁ offspring				F ₂ offspring			
	♀		♂		♀		♂	
	Muscled	Muscleless	Muscled	Muscleless	Muscled	Muscleless	Muscled	Muscleless
K♀ $\times$ K♂	0	17	21	0	0	11	10	0
K♀ $\times$ N♂	0	17	18	0	5 ^b	17 ^b	17	0
N♀ $\times$ K♂	0	18	16	0	4 ^b	15 ^b	16	0
N♀ $\times$ N♂	9	0	11	0	7	0	8	0

^a K: Kanaya, N: Naganuma.

^b Comparison with 1:3 ratio, $p=0.517$ and 0.465 (binominal test).

(ROFF, 1986). The present study of *H. picea* showed that the flight muscle dimorphism of the female adults is also a simple Mendelian trait, with the muscleless form dominant to the muscled one. However, it should be noted that the male adults of this species had flight muscles. This indicates that the males are always characterized by the muscled form irrespective of their genotypes. In the case of a single-locus, two allele system with brachyptery dominant, it is postulated that each allele acts additively to determine the level of the wing suppressor substance, such as the juvenile hormone (ROFF, 1986). If this is also true for the flight muscle form, the level of the flight muscle suppressor should be lower than a threshold level only in the recessive homozygote in the females, and should also be lower than in all the genotypes of the males. Further studies are necessary to clarify the ontogenic and endocrinologic systems of the flight muscle dimorphism in this species.

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