Hybridization between *Tribolium freemani* HINTON and
Tribolium castaneum (HERBST), and Some Preliminary
Studies on the Biology of *Tribolium freemani*
(Coleoptera : Tenebrionidae)

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Crosses between *Tribolium freemani*, recently rediscovered from imported corn in Japan, and *T. castaneum* produced many infertile F₁ hybrids. Weights of hybrid pupae were intermediate between those of parents, and the weight ratio between the sexes differed in the two parental crosses. The optimum conditions for development of *T. freemani* were similar to those of *T. castaneum* but the developmental period was slightly longer. The ease with which *T. freemani* was reared on wheat-feed medium suggests that it could become a pest of stored products. However, the absence of records of this species since late last century suggests that it is, at present, of negligible economic importance or extremely localized.

INTRODUCTION

Several species of the genus *Tribolium*, i.e. *T. castaneum*, *T. confusum*, *T. madens* etc., are of interest to economic entomologists because of their pest status in stored products. These species are also of interest to ecologists, physiologists and geneticists as experimental animals. In the genus *Tribolium*, the *castaneum*-section of the *castaneum* species-group includes four species, *T. castaneum*, *T. freemani*, *T. madens* and *T. audax* (HINTON, 1948; HALSTEAD, 1969). Of these, *T. freemani* was the only species whose biology was not known, since the species was known only from an individual female adult, which was collected at Hispar, Kashmir in India, at the end of last century, 189(3?)

Recently, adults of *T. freemani* (identified by Dr. D. G. H. HALSTEAD, Slough Laboratory, Ministry of Agriculture Fisheries and Food, England) were intercepted in Japan. These adults were taken into culture and successfully reared.

In this paper, we report on the hybridization between *T. freemani* and *T. castaneum* and also describe some preliminary studies on the biology of *T. freemani*.

MATERIALS AND METHODS

Origin of strains and culture conditions. A light infestation of *T. freemani* was intercepted in Japan in 1978 in a shipment of maize imported from Brazil. It was not possible, however, to determine whether the infestation originated in Brazil or was acquired during shipment from residues of a previous cargo. The *T. castaneum* used in this study was a laboratory-selected, phosphine-resistant strain (NAKAKITA and WINKS, 1981).

Both species were reared on wheat-feed (<0.25 mm particle size) at $30\pm 2^\circ\text{C}$ and $70\pm 5\%$ R.H.

Development time for T. freemani. The hatchability of eggs and the developmental period of *T. freemani* were examined at 22 and 75% R.H., at temperatures of 25, 30 and 33°C . Following a 24 hr oviposition period in wheat-feed medium at 30°C , 70% R. H., batches of 50 eggs were separated from the medium by sieving and were placed in empty vials (55 mm deep, 25 mm dia). The hatchability of eggs was determined from three batches of eggs at each of the experimental conditions. The developmental period of *T. freemani* was determined from three batches of 20 newly-hatched larvae placed in a vial containing a 4 cm layer of wheat-feed.

Interspecific hybridization. Newly-formed pupae of each species were sexed, weighed and segregated individually in small vials (55 mm deep, 25 mm dia.) until the adults emerged. Both combinations of single-pair crosses of one-week-old adults of *T. freemani* and *T. castaneum* were established in vials containing 5 g of wheat-feed.

Five replicates of each pair were placed in an incubator maintained at 30°C and 70% R.H. After 2 weeks, all parental adults were removed from each vial. The F_1 pupae were counted, sexed and individually weighed. To determine the fecundity of hybrid adults, filial crosses were established together with all possible crosses with the parent strains.

RESULTS

Figure 1 shows a dorsal view of adults of *T. freemani* and *T. castaneum*. *T. freemani* is very similar to *T. castaneum* in external characteristics including shape and color (dark reddish-brown) but is considerably larger. Differences in pupal size between *T. freemani* and *T. castaneum* are evident from the data of Table 1. The mean weight of female pupae of *T. freemani* was 2.3 times greater than that of female pupae of *T. castaneum*. The corresponding factor between males was 2.4. The body length and pronotum width of *T. freemani* pupae were from 1.34 to 1.39 greater than those of *T. castaneum*.

The median developmental periods of eggs, larvae and pupae of *T. freemani*, together with the fertility of eggs and the natural mortality that occurred during larval development, are given in Table 2. The duration of the larval period was affected by both temperature and relative humidity while that of the egg and pupal stage was influenced mostly by temperature. The fertility of eggs at 22% R.H. decreased from 96 to 90% with increasing temperature from 25 to 33°C . At 75% R.H., temperature appeared to have little effect on fertility which was greatest at 30°C . Larval mortality was higher at 22% R.H. than at 75% R.H. at each temperature and was greatest at 33°C , 22% R.H. The lowest larval mortality was obtained at 30°C , 75%

Fig. 1 Dorsal view of adult of *Tribolium freemani* (Left) and *Tribolium castaneum* (Right).

Table 1. COMPARISON OF BODY MEASUREMENTS OF PUPAE OF *T. freemani* AND *T. castaneum*

		Mean $\pm$ S.E. ^a					
		Body weight (mg)		Body length (mm)		Pronotum width (mm)	
<i>T. freemani</i>	♀	5.655 $\pm$ 0.05	(144)	5.299 $\pm$ 0.04	(32)	1.519 $\pm$ 0.02	(32)
	♂	5.377 $\pm$ 0.05	(123)	5.215 $\pm$ 0.04	(26)	1.570 $\pm$ 0.05	(26)
<i>T. castaneum</i>	♀	2.449 $\pm$ 0.03	(32)	3.940 $\pm$ 0.04	(22)	1.133 $\pm$ 0.01	(22)
	♂	2.250 $\pm$ 0.03	(30)	3.811 $\pm$ 0.02	(23)	1.126 $\pm$ 0.01	(23)

^a Figures in parenthesis are the number of pupae used in measurements.

R.H. Although the shortest median development time from egg to adult occurred at 33°C, 75% R.H., under these conditions, egg hatchability was slightly lower and larval mortality slightly higher than at 30°C, 75% R.H. The number of adult progeny from crosses between *T. freemani* and *T. castaneum* is given in Table 3. The total number of progeny from both crosses indicated that interspecific reproduction had been successful. However, the sex ratio of the adult progeny was considerably distorted and in each of the two crosses, favored that of the *T. freemani* parent.

The weights of pupae of *T. freemani* and *T. castaneum* were compared with the weights of pupae of F₁ hybrids (Figs. 2 and 3). In both crosses, the weights of the hybrid pupae were intermediate between the weights of parent pupae. Male pupae from female *T. freemani* crossed with male *T. castaneum* were distinctly heavier than female pupae (Fig. 2) whereas those from the reciprocal cross were distinctly lighter than female pupae (Fig. 3). The weights of female pupae from both crosses were similar.

From all matings of F₁ progeny, both filial crosses and crosses with the parent

Table 2. MEDIAN DURATION OF EGGS, LARVAE AND PUPAE OF *T. freemani* AT DIFFERENT TEMPERATURES AND RELATIVE HUMIDITIES

°C	RH%	Duration in days and mortality (%)			Total Period
		Egg	Larva	Pupa	
25	22	4.7 (96) ^a	71.4 (20.0) ^b	11.8	87.9
	75	4.5 (94)	53.2 (16.7)	9.0	66.7
30	22	3.4 (92)	33.8 (10.0)	7.3	44.5
	75	3.1 (96)	28.9 (3.4)	6.3	38.3
33	22	2.8 (90)	29.5 (33.4)	5.7	38.0
	75	2.6 (94)	23.1 (5.0)	5.2	30.9

^a Hatchability (%)

^b Mortality (%)

Fig. 2 Distribution of pupal weight of *T. freemani* females, *T. castaneum* males and their F₁ progeny.

Table 3. TOTAL NUMBER OF HYBRID ADULTS OBTAINED FROM CROSSES BETWEEN *T. freemani* AND *T. castaneum*

Cross	No. of progeny ^a			Sex ratio ♀/♂
	♂	♀	Total	
♀ <i>T. freemani</i> × ♂ <i>T. castaneum</i>	37 (7.4±3.9) ^b	118 (23.6±5.9)	155	3.2 : 1
♂ <i>T. freemani</i> × ♀ <i>T. castaneum</i>	179 (35.8±4.4)	96 (19.2±3.0)	275	0.5 : 1

^a Total adult progeny from five pairs of parents.^b Figures in parenthesis are the average number of progeny per female ±S.D. Fig. 3 Distribution of pupal weight of *T. castaneum* females, *T. freemani* males and their F_1 progeny.

strains, no F_2 progeny were produced. Cultures containing these crosses were observed over a period of more than 6 months. These results indicate that both the male and female hybrids were sterile.

DISCUSSION

The identification of the insect that was the subject of the present study was made

by Dr. D. G. H. HALSTEAD, who referred to the external characteristics of the single female described by HINTON (1948). To verify the identification of this species and to acquire additional taxonomic information, such as details of male genitalia, HALSTEAD (personal communication) is attempting to obtain specimens of *T. freemani* from India, the country of origin of this species.

T. freemani was successfully reared on the standard wheat-feed medium used for *T. castaneum*, *T. confusum* and many other stored product species. This strongly suggests that *T. freemani* can be a pest of stored products. A comparison with other *Tribolium* species (HOWE, 1956, 1960 and 1962) indicates that *T. freemani* has a slightly longer larval period than those of *T. castaneum*, *T. confusum* and *T. madens* but is similar to these species in other respects including the optimum conditions for development. In the present study, the optimum conditions for development of *T. freemani* appeared to be 30°C, 75% R.H. While the development time was slightly longer, the survival rate of eggs and larvae at 30°C, 75% R.H. was higher than at 33°C, 75% R.H. In spite of the similarities between *T. freemani* and known pest species such as *T. castaneum* and *T. confusum* the absence of records of *T. freemani* particularly from stored products suggests that it is, at present, of negligible economic importance or extremely localized.

The production of infertile hybrid progeny by *T. freemani* and *T. castaneum* indicates that *T. freemani* is a sibling species of *T. castaneum*. This is the first record of a hybrid produced from *T. castaneum* and the second such report from within the genus *Tribolium*. HALSTEAD (1969) obtained F₁ hybrids from a cross between *T. madens* and *T. audax*. All reports to date of hybrids from within the genus *Tribolium* are from the close species of the *castaneum*-section of the *castaneum* species-group in spite of the fact that there are at least 33 species in 5 species-groups of this genus (HINTON, 1948; SOKOLOFF, 1972).

SOKOLOFF (1974) lists 8 species of *Tribolium* as pests, or potential pests of stored products. *T. castaneum* and *T. confusum* are the most serious pests of a wide range of stored products. *T. destructor*, *T. madens*, *T. anaphe* are described as potential pest species which have begun to move into stored products. *T. brevicornis* and *T. parallelus* in the *brevicornis* subgroup and *T. thusa* in the *confusum* subgroup are less important but could become pests of stored products. For example, SOKOLOFF was able to rear *T. brevicornis* in the laboratory in medium used to rear *T. castaneum* and *T. confusum*. To this list of species *T. audax* (HALSTEAD, 1969) should be added as a ninth species but with similar pest status as *T. madens* and, based on the present study, *T. freemani* should be added as a tenth species.

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