

POLYMORPHISM IN THE ADULT OF CALLOSOBRUCHUS MACULATUS -
A POSSIBLE PROCESS OF EVOLUTION TO STORED PRODUCT PEST.*

Syunro Utida
Entomology Laboratory
Kyoto University
JAPAN

In the population of southern cowpea weevil, *Callosobruchus maculatus*, there are two morphologically distinct forms of adult. One is dark and the other is rather light. Based upon their behavior, these were called the flightless form and the flight form by the author [1], and the normal form and the active form by Caswell [2].

PROCESS OF ADAPTATION TO A LIFE IN STORED BEANS: Each adult form is induced mainly by the difference in density of the larval population in beans in the younger larval stages. The flight form emerges in high percentage in crowded larval populations which causes the temperature to rise in a heap of beans by the accumulation of the metabolic heat of the larvae. The rise of temperature is a true cause physiologically, but secondarily and indirectly in an ecological sense, the larval crowding is the primary and original cause [1,3,4]. Subsidiary factors responsible for the production of the flight form are the low water content of the beans and the continuous darkness (or continuous light) [1,3,5].

The latter two conditions are characteristic of bean storage in a warehouse, and the former condition of heavy weevil infestation occurs inevitably in storage. Thus, under storage conditions a high percentage of the flight form might well develop as shown in the observations on a bean store in Nigeria [6,7].

Although the flight form emerges under storage conditions, every character - morphological and physiological - of the flight form seems to be less adapted to life under storage conditions, [8,9]. The flight form is apt to fly to the out-of-doors by positive phototaxis without depositing any egg on beans. During several days after emergence the flight form becomes rather inactive not only in reproduction but in behavior. After leaving the emergence site, the flight form seeks out a site of bright and whitish background and forms an aggregation with several other individuals. In this aggregation, the sexual maturation of the female seems to be retarded (Utida, in prep.). As the result of this sequential behavior pattern, eggs of the flight form are rarely deposited on stored beans. Even if the female could not leave the stored beans, only a small number of her eggs might be deposited there, because of her low fecundity and late maturation. Therefore, the flight form may leave scarcely any progeny for the next generation on the beans in storage.

Next, it must be noted that each form has a tendency to produce its own respective form of progeny. But, this tendency

for the flight form can not be detected during any two consecutive generations and at length it becomes barely detectable at the fifth or greater number of generations. It is supposed that this tendency is due to genetic factors governed by polygenes.

When populations were bred continuously under controlled laboratory conditions, comparable to bean heaps in a warehouse, the percentage of the flight form changed with the lapse of generations as shown in Fig. 1.

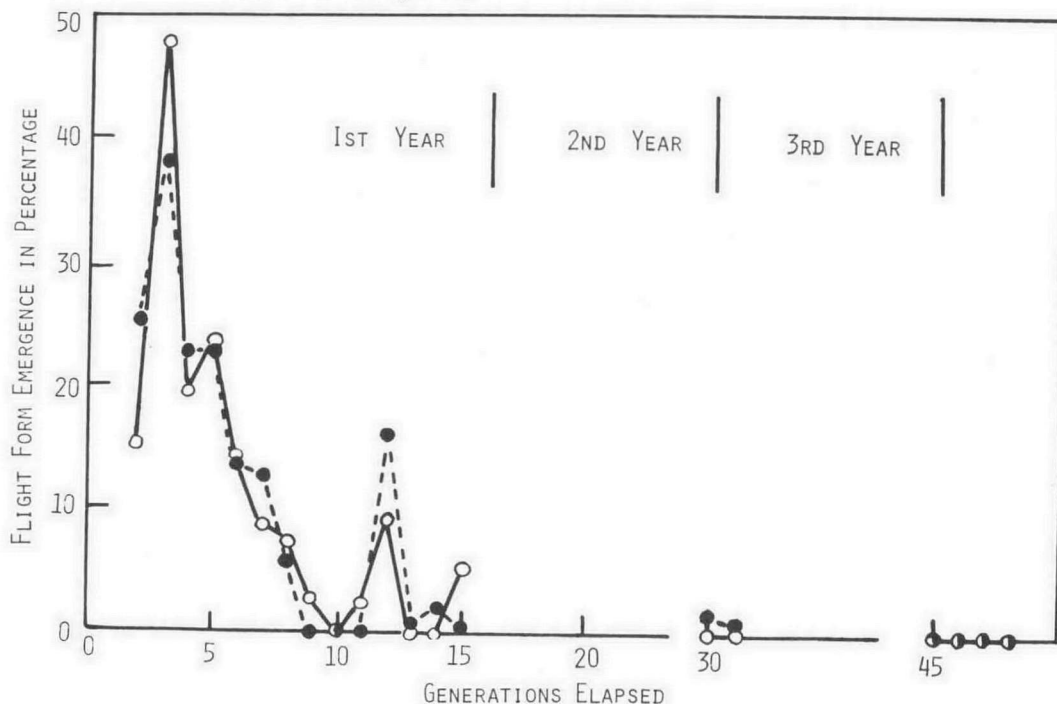


FIGURE 1. Change of percentage emergence of the flight form with the lapse of generations. -O-: female, -●-: male.

The percentage was high in the early generations, but decreased gradually and after about 30 generations dropped to one or two percent. Finally, at about the 50th generation no individuals of the flight form were found. A similar decreasing trend of flight form emergence was observed by Caswell [2] in Nigeria.

This disappearance of the flight form can be explained by two processes. In each generation, selection operates in favour of the flightless form, because this form lays more eggs and lays them earlier, the flight form having both a longer developmental period and a longer preoviposition period. If it were able, the flight form would probably leave the culture. The second process is the intrinsic genetic factor determining the forms.

Under conditions of bean storage these processes are operative and the flightless form is fixed and the flight form disappears from the population in the long run.

POLYMORPHISM IN THE DOMESTIC ENVIRONMENT: Many species in the family Bruchidae are pests of stored beans, but many others

develop on the seeds of leguminous plants in the field and do not injure seed in storage.

Both the pea weevil, *Bruchus pisorum*, and the broad bean weevil, *B. rufimanus*, deposit their eggs on the surface of young bean pods and their larvae bore into the seed. Their adults emerge after the seeds are harvested but they remain inactive in the seeds until the next spring. In the spring they fly to the field, where their ovaries mature after they feed on the pollen or honey of their host plant.

On the other hand, weevils of the genus *Callosobruchus*, the azuki bean weevil, *C. chinensis*, for instance, differ from those of the genus *Bruchus* in their life history. After the bean is harvested, the weevil has only a short dormant period. In the stored bean, the weevils belonging to *Callosobruchus* can complete their life cycles repeatedly, because their ovaries mature without migration to the field and feeding on pollen. Furthermore in the Mexican bean weevil, *Zabrotes bifasciatus*, the complete life cycle is spent in storage.

It is commonly said that pests of plant seed may be classified into the following three types; (1) those feeding on the seeds of plants growing in the field, (2) those feeding on stored seed, (3) those infesting seed under both habitats. As examples, *B. pisorum* and *B. rufimanus* belong to type (1), several species of *Callosobruchus*, including *C. maculatus* and *Acanthoscelides obtectus*, are type (3), and *Z. bifasciatus* may be type (2). Generally, stored product pests belong to type (2) and (3). These three types are distributed in different genera and represent a series in systematics from most primitive to most specialized.

This serial change in the infestation type is also reflected in many morphological, physiological and ecological characters. as well, namely (in the Bruchids) in dwarfism, pubescence on the body surface, voltinism, diapause in the adult stage, length of the prematuration period or precosity, fecundity, water content and fat content of the body, flight activity, monophagy or polyphagy, and so on. Each character changes in association as shown in Table I. Change in any one character among these several characters is not important for the differentiation of the three types. For example, a change in the diapausing character could not in itself, produce an adaptation to stored conditions. Changes in association of several characters is necessary for the establishment of life under domestic conditions.

Such changes in association in several characters, as seen in the inter-genus relation in the Bruchidae, can be found in many diverse groups. Hovanitz [10] found this associative change in physiological and morphological characters in the genus *Drosophila*, the genus *Colias* and several genera of mosquitoes, *Culex*, *Anopheles* and *Haemagogus*. Kiritani [11,12] also discussed a similar phenomenon found in some stored product pests in relation to the adaptive differentiation of the species to the life under storage conditions. As an example, the case of the rice weevil, *Sitophilus*, are given in Table II. *Sitophilus zeamais*

and *S. oryzae* are in a relation of sibling species. The former species belongs to type (3) and the latter to type (2). The whole relation given in Table II coincides well with the case of Bruchidae. The changes in association in physiological and morphological

TABLE I. Table showing that the difference in biological characters between two forms in *Callosobruchus maculatus* is very similar to those between *Bruchus rufimanus* and *Zabrotes bifasciatus* belonging taxonomically remote genus

	<i>Callosobruchus maculatus</i>			
	<i>Bruchus rufimanus</i>	Flight form	Flightless form	<i>Zabrotes bifasciatus</i>
Pubescence on elytra	dense	dense	thin	thin
Diapause in adult (Sexual maturity at emergence)	sexually immatured	sexually immatured	sexually matured	sexually matured
Adult longevity	several months	15 days	7 days	7 days
Flight activity	fly	fly	can't fly	can't fly
Water content of body in per cent	45 - 50	45 - 50	55	60
Fat content of body in per cent	high	24 - 26	13 - 15	low

TABLE II. Comparison of several biological characters between two sibling species of the rice weevil.

	<i>Sitophilus zeamais</i>	<i>Sitophilus oryzae</i>
Body size	large (3.8 mm)	small (2.5 mm)
Body wall	hardly chitinised	relatively soft
Water content of body	low	high
Diapause	?	no
Prematuration period	8 - 9 days	6-7 days
Adult longevity	long (25 weeks)	short (15 weeks)
Flight activity	fly	can't fly
Hibernacula	out of doors	in grain

characters are seen among the species in a genus or among the species belonging to different genera in a family. It must be noted, furthermore, that the association of characters is rather common in

each species group, regardless of its position in phylogeny.

It should be emphasized here that these changes in association among different groups in taxonomy are nicely represented in the differences of characters between the two forms, the flight and the flightless form of *C. maculatus*. The difference in characters between two forms is similar to that between *Bruchus rufimanus* and *Zabrotes bifasciatus*. (Table 1).

Polymorphism can be interpreted to be comparable with different stages in post-embryonic development, as elucidated by Wigglesworth [13]. Therefore, it seems to be not illogical that the differential characters among species in a group just coincide with the polymorphic characters in a species.

A similar phenomenon of polymorphism has been observed in *Bruchidius alfieri* and *B. trifolii* [14,15]. The former species attacks stored clover seed and the latter injures clover seed growing in the field. Both have been dealt with as different species in taxonomy, based on knowledge of their morphology, life history and behavior. Recently, however, it was shown that both are only polymorphs belonging to the same species and are interchangeable with each other by rearing under different environmental conditions or at different seasons. The differences between both forms coincides exactly with the present case of the cowpea weevil.

Similar cases will be found with the accumulation of knowledge on life histories not only in the family Bruchidae but also in many other taxonomic groups. Environments that are newly created by human activity, such as the storage of beans, and other products fabrics, the urban environment, sewers, etc. may be occupied by newly evolved variants which adapts their lives to the new environments through processes similar to the present case of the bean weevil.

REFERENCES:

- [1] Utida, S., Phase dimorphism observed in the laboratory population of the cowpea weevil, *Callosobruchus quadrimaculatus*. Jap. Jour. Appl. Zool., 18 (1954) 161-168.
- [2] Caswell, G. H. Observations on an abnormal form of *Callosobruchus maculatus*. Bull. ent. Res., 50 (1960) 671-680.
- [3] Utida, S., Phase dimorphism observed in the laboratory population of the cowpea weevil, *Callosobruchus quadrimaculatus*, IV. The mechanism of induction of the flight form. Jap. Jour. Ecol. 15 (1965) 193-199.
- [4] Sano, I., Density effect and environmental temperature as the factors producing the active form of *Callosobruchus maculatus*. Jour. stored Prod. Res., 2 (1967) 187-195.
- [5] Utida, S., Photoperiod as a factor inducing the flight form in the population of the southern cowpea weevil, *Callosobruchus maculatus*. Jap. Jour. appl. Ent. Zool., 13 (1969) 129-134.
- [6] Prevett, P. F., Field infestation of cowpea (*Vigna unguiculata*) pod by beetles of the families Bruchidae and Curculionidae in Northern Nigeria. Bull. Ent. Res., 52 (1961) 635-645.

- [7] Taylor, T. A. and Agbaje, L. A., Flight activity in normal and active forms of *Callosobruchus maculatus* in a store in Nigeria. Jour. stored Prod. Res. 10 (1974)9-16.
- [8] Utida, S., Density dependent polymorphism in the adult of *Callosobruchus maculatus*. Jour. stored Prod. Res., 8 (1972) 111-126.
- [9] Utida, S., Yasui, M. and Kawada, K., Some morphological differences in the two adult forms in *Callosobruchus maculatus*. (in this issue).
- [10] Hovanitz, W., Occurrence of parallel series of associated physiological and morphological characters in diverse groups of mosquitoes and other insects. Contrib. Lab. Verteb. Biol. Michigan Univ., 32 (1947) 1-24.
- [11] Kiritani, K., Biology of Bruchidae and the process of its adaptation to indoor conditions. Sin-Kontyu, 9 (1956) 7-11.
- [12] Kiritani, K. The origin of the household pests, and the process of adaptation to indoor conditions. Insect Ecol. Tokyo, 9 (1961) 22-40.
- [13] Wigglesworth, V. B., The physiology of insect metamorphosis, Cambridge University Press, (1954).
- [14] Abou-Raya, A. K. *Bruchidius alfieri* Pic, a biologic race of *Bruchidius trifolii* Motsch. Bull. Soc. Fouad I Ent., 38 (1954) 193-203.
- [15] Hafex, M. & Osman, F. H., Biological studies on *Bruchidius trifolii* and *Bruchidius alfieri* in Egypt. Bull. Soc. Entom. Egypte, 11 (1956) 231-277.