Geographic Variation in Male Antenna of the Azuki Bean Weevil, *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae)¹

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The ratio of the width of apical third segment of the antenna, Q , to the head width, C , was used as an index of antennal pectination in *C. chinensis*. Western (Ethiopian, Iranian and Indian) strains showed smaller values of Q/C than eastern (Chinese, Korean and Japanese). The reduced pectination of the male antennae in the western strains is assumed to be caused by the its long indoor life on the seeds of Viciae legumes, i.e. peas, horse beans or lentils which serve as only storage host of the bruchid.

INTRODUCTION

The azuki bean weevil, *Callosobruchus chinensis* (L.), infests several kind of legume seeds and causes serious damage especially in East Asia. APPLEBAUM et al. (1968) found that the Israeli strain had serrate male antennae (Fig. 1-I), while those of the Japanese strain were pectinate (Fig. 1-II). 'Serrate' and 'pectinate' represent the extremes of graded character states. Specimens with antennae of intermediate states are often encountered, however (APPLEBAUM et al., 1968).

We propose here an index to quantify this antennal character and discuss its variability in analyzing the life cycle evolution and the extension of geographic distribution in the species.

MATERIALS AND METHODS

Antennal pectination index. A preliminary observation revealed that the apical third to fifth segments of the antennae of *C. chinensis* and *C. maculatus* were almost equal in width and wider than the others. The degree of antennal pectination can be represented by Q/C , Q being the width of apical third segment and C the head width (Fig. 1-III). The larger the ratio Q/C the more pectinate is the antenna. Q and C were measured with a micrometer set in a dissecting microscope.

Specimens examined. The origins of geographical strains of *C. chinensis* are shown in Table 1.

Allometric growth. HUXELY (1932) discussed the 'problems of relative growth' and defined 'differential growth' or 'heterogony' as the phenomenon that the proportion of

¹ This work was conducted in the Plant Quarantine Research Center, Yokohama, Japan.

Fig. 1. Male heads of *C. chinensis* showing difference in antennal pectination between Japanese (I) and Ethiopian (II) strains, and antennal pectination index Q/C , (III).

Table 1. Sources of specimens examined in *C. chinensis*

Code	Locality	Collection
<i>Foreign strains</i>		
E1	Ethiopia	Qi: <i>Vicia faba</i> , 2-III-'67.
E2	Do	Qi: Do, 9-III-'70.
E3	Do	Qi: Do, 1-V-'71.
E4	Do	Qi: Do, 16-IV-'73.
IR1	Iran (from Liban)	Qi: <i>Lens culinaris</i> , 15-III-'55.
I1	India	Dead specimen, '81.
B1	Burma (from Rangoon)	Qi: <i>Vigna</i> sp., 14-II-'61.
B2	Do	Qi: <i>Cicer arietinum</i> , VI-'54.
C1	China (from Hong-Kong)	Qi: <i>Vigna</i> sp., 5-Vi-'60.
C2	Do (Hopeh State)	Ts: <i>V. angularis</i> in field, XI, '81.
C3	Do (from Shanghai)	Qi: <i>V. angularis</i> , 19-V-'83.
C4	Do	Qi: <i>V. unguiculata</i> , 17-IV-'86.
K1	Korea (from South Korea)	Qi: <i>V. radiata</i> , 31-X-'67.
K2	Do	Qi: <i>Vigna</i> sp., 11-XI-'71.
K3	Do	Qi: <i>V. radiata</i> , 22-XI-'76.
K4	Do	Qi: Do, VIII-'83.
<i>Japanese strains</i>		
JA1	Hirosaki City, Aomori Prefecture ("P." later)	Ts: stored beans before selling, '69.
JW1	Morioka City, Iwate P.	Ts: beans in field, '69.
JN1	Nagaoka City, Niigata P.	Ts: stored beans before selling, '69.
J11	Tsukuba-gun, Ibaraki P.	Ts: <i>V. angularis</i> in field, X-'81.
JT1	Tokyo?	Ts: refer to ISHII (1952).
JC1	Matsudo City, Chiba P.	<i>V. unguiculata</i> in field, X-'81.
JK1	Kyoto City	<i>Cereal-chandler</i> , refer to UTIDA (1941).
JO1	Yoshii-cho, Akaiwa-gun Okayama P.	<i>V. angularis</i> in field, X-'83, sent by Dr. YOSHIDA, Okayama Univ.
JS1	Taisha City, Shimane P.	Ts: stored beans before selling, '69.
JK02	Yusuhara-cho, Takaoka-gun, Kochi P.	Harvested <i>V. angularis</i> , X-'84., sent by Mr. HIROSE, Moji Plant Prot. Sta.

Qi: specimens by plant quarantine interception, Ts: dead specimens were sent by Dr. FUJII who had kept the populations in the laboratory of Tsukuba Univ. under special plant quarantine permit for exotic populations.

the size of an organ to that of another organ is changed with the body size. If there is such a relationship between Q and C , it should be taken into account in the comparison of antennal pectination between individuals of different body size.

A random sample of 50 individuals each from the Ethiopian (E3) and Japanese (J01) strains and 30 individuals from an Indian (I1) strain showed no significant allometric relationship between Q and C within the strains. When extremely small individuals were taken from a large sample of the Japanese strain, J01, reared in the laboratory, their average Q/C ratio was smaller than that of the random sample. Such small individuals, however, were very few and the effect of heterogony could be removed by excluding them.

RESULT

The western (Ethiopian, Iranian and Indian) strains had smaller Q/C than the eastern (Chinese, Korean and Japanese) (Figs. 2 and 3). Two Burmese strains were intermediate between them in ratio. One of the Korean strains (K4) showed two peaks and a wide range of variation in Q/C .

Fig. 2. Degree of male antennal pectination, as represented by Q/C , in foreign strains of *C. chinensis*.

Fig. 3. Degree of male antennal pectination, as represented by Q/C , in Japanese strains of *C. chinensis*. Numbers in $\square$: generations in laboratory, $\ast$: rough estimations.

Fig. 4. Relationship between the mean degree of male antennal pectination and number of laboratory generations in Japanese strains of *C. chinensis*.

Among the Japanese strains which had been originally collected from areas ranging northeast to southwest in this country, no geographic trend was detected in Q/C value (Fig. 3) but the average value varied with the number of generations spent in the

laboratory (Fig. 4). The mean degree of antennal pectination decreased during the first 50 generations. This secular change appeared also in JC1 strain which initially showed two peaks of Q/C distribution, one with a very high value (Fig. 3). After 12 laboratory generations, this peak in the higher range disappeared and the mean Q/C decreased (JC1-b, in Fig. 3).

DISCUSSION

Before discussing the variation in antennal character, the biogeographic relation between the bruchids and their hosts must be mentioned.

Relationship between host species and life cycles of the bruchids

All the wild bruchids whose hosts have been found to date are entirely or nearly monophagous, while the bruchids attacking both field and stored pulses such as *C. chinensis* or *C. maculatus* have much wider host ranges (SOUTHGATE, 1981).

Several authors presented host lists of the bruchids attacking stored pulses, but few

SPACE	LIFE CYCLE	CATEGORY OF HOST	HOST SPECIES		TRIBE
			<i>C. chinensis</i>	<i>C. maculatus</i>	
FIELD		WILD HOST	<i>Vigna angularis</i> var. <i>nipponensis</i>	<i>V. unguiculata</i> (wild type)	PHASEOLEAE
		PRIMARY HOST	<i>V. angularis</i> <i>V. unguiculata</i> <i>V. radiata</i> <i>Cajanus cajan</i>		
STORAGE		SECONDARY HOST		<i>V. angularis</i> <i>Pisum sativum</i> <i>Cicer arietinum</i> <i>Lens culinaris</i> <i>Vicia faba</i>	VICEAE

Fig. 5. Life cycle patterns of *C. chinensis* and *C. maculatus*. The life cycle on wild host is hypothetical. Host plants were classified into three groups according to ALZOUMA (1981), ARORA (1977), BATO and SANCHEZ (1972), DAVIES (1959), LARSON and FISHER (1938), SHINODA and YOSHIDA (1985), and YOSHIDA et al. (1984).

of them gave the reason why this type of bruchids had a wide host range. KIRITANI (1961) and UMEYA (1981) noticed that the host range of these bruchids was wider under storage conditions than under field conditions, and inferred that the bruchids were mono- or oligophagous in the pre-agriculture times.

The hosts of the bruchids attacking both field and stored pulses are classified into three groups: ① 'wild hosts' attacked only in the field, ② 'primary hosts' attacked both in the field and in storage, and ③ secondary hosts' attacked only in storage, where ② and ③ are cultivated and harvested unlike ① (WATANABE, 1985).

Figure 5 indicates the relationship between the host species and the life cycles of *C. chinensis* and its allied species, *C. maculatus*. The figure shows not only the present but also hypothetical past situations. Both bruchids might have originally infested Phaseoleae legumes and then begun to attack Viciae beans under storage conditions.

According to MAEDA (1978), these pulses originated in Eurasia and Africa as shown in Fig. 6. At present Viciae pulses, which serve as secondary host for the *Callosobruchus* species, are common in the Mediterranean Basin, Southwest Asia and the Indian Subcontinent. On the Contrary, Phaseoleae beans are mainly raised in Tropical or South Africa, and East Asia (MAEDA, 1986).

Geographic origins of the bruchids

We may focus our interest on Eurasia and Africa, because the hosts of *C. chinensis* and *C. maculatus* originated in these areas, and the genus *Callosobruchus* had its origins in Asia and Africa (SOUTHGATE, 1978).

In *C. maculatus*, two morphologically distinct adult forms are known, one breeding

Fig. 6. Origins of cultivation of pulses listed in Fig. 5.

Fig. 7. Comparison in degree of male antennal serration, as represented by Q/C , between flight and flightless forms of *C. maculatus*. The specimens of the flight form obtained by courtesy of Dr. S. UTIDA, were derived from a strain of North American origin and by this UTIDA (1954) first found both forms. As specimens of the flightless forms of this strain were unavailable, those of Siamese strain were used here.

in stored beans and the other infesting field crops. These were called the flightless form and the flight form respectively by UTIDA (1954). Certain morphological or physiological features of the two forms are adaptive to their field and indoor lives, respectively (UTIDA, 1972). The application of Q/C to these forms showed that the flight forms had more serrated male antennae than the flightless forms (Fig. 7). Both forms occur within the same strain like phase dimorphism, but after many generations of laboratory culture the strain did not produce flight forms even when environmental conditions were favorable for their production (UTIDA, 1970, 1972).

A similar trend was observed in the Japanese JK1 strain of *C. chinensis* after about 600 laboratory generations. This strain was sluggish and rarely flew, while other Japanese strains that had been kept in laboratory culture for only a few generations were much more active. This variation in activity is associated with the degree of pectination of the male antennae and regarded as an adaptation to the change in mode of life: 'field to storage'.

It might be inferred that the strains of the bruchids in their original locality still infest wild or primary hosts in the field. The field infestations of *C. maculatus* on both wild and cultivated cowpeas, *Vigna unguiculata*, have been reported from the West Coast of Tropical Africa (ALZOUMA, 1981). The bruchid, therefore, probably originated in this area which is also assumed to be the original land of cowpea (FARIS, 1965).

On the other hand, field infestations of *C. chinensis* are common not in Africa but in Japan and other East Asian countries. The Indian Subcontinent seems to be excluded as a location of geographic origin, because field infestations of *C. chinensis* rarely occur there (SKAIFE, 1926). The beetle requires subtropical temperature conditions (UMEYA et al., 1970; UTIDA, 1971), so that its origin may not be the Far East but somewhere in south China or Indo-China.

Geographic variation in antennal pectination

The records of plant quarantine interception (Table 1) suggest that the Ethiopian and Iranian populations of *C. chinensis* live on secondary hosts in storage but the Chinese and Korean populations depend on primary hosts. As mentioned above, it is likely that *C. chinensis* originated in Southeast Asia and extended to the Near East and the Mediterranean Basin. It infests only stored beans and peas in the latter areas where there are no or few field (primary) hosts. The long-continued indoor life might have caused the retrogression of the male antennae.

This evolutionary change may proceed more quickly in warehouses than in the laboratory, because in semi-open conditions of warehouses, active individuals with well developed antennae would have more opportunity to escape and die.

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REFERENCES

- ALZOUMA, I. (1981) Observation of the ecology of *Brucidius atrolineatus* PIC and *Callosobruchus maculatus* L.

- (Coleoptera: Bruchidae) in Niger. In *The Ecology of Bruchids Attacking Legumes (pulses)*. Series Entomologica, Vol. 19, Dr. Junk Publishers, The Hague, pp. 205–221.
- APPLEBAUM, S. W., B. J. SOUTHGATE and H. PODLER (1968) The comparative morphology, specific status and host comparability of two geographical strains of *Callosobruchus chinensis* L. (Coleoptera, Bruchidae). *J. stored Prod. Res.* **4**: 135–146.
- ARORA, G. L. (1977) Bruchidae of Northwest India. *Oriental Insects Supplement* No. 7, 132 p.
- BATO, S. M. and F. F. SANCHEZ (1972) The biology and chemical control of *Callosobruchus chinensis* (LINN.) (Coleoptera: Bruchidae). *Philippine Ent.* **2**: 167–182.
- DAVIES, J. C. (1959) A note on the control of bean pests in Uganda. *E. Afr. agric. J.* **24**(3): 174–178.
- FARIS, D. C. (1965) The origin and evolution of the cultivated forms of *Vigna sinensis*. *Can. J. Genet. Cytol.* **7**: 433–452.
- HUXLEY, J. S. (1932) *Problems of Relative Growth*. Methuen & Co., London, 132 p.
- ISHII, S. (1952) Studies on the host preference of the cowpea weevil (*Callosobruchus chinensis* L.) *Bull. Nat. Inst. Agr. Sci.* C-1. 185–256.
- KIRITANI, K. (1961) The origin of the household pests and the process of adaptation to indoor conditions. *Seitai-Konchū* **9**: 22–40 (in Japanese).
- LARSON, A. O. and C. K. FISHER (1938) The bean weevil and the southern cowpea weevil in California. *U.S. Dept. Agric. Tech. Bull.* **593**: 1–170.
- MAEDA, K. (1978) Initiation pulse cultivation in world-wide origin of agriculture. *Nōgyō-gijutsu* **33**: 271–276 (in Japanese).
- MAEDA, K. (1986) Legumes: Past, present and future. In *Distribution and exploration for germplasm of crops in Tropical area*. Occasional Papers No. 9, Kagoshima University Research Center for South Pacific: 1–31 (in Japanese with an English summary).
- SHINODA, K. and T. YOSHIDA (1985) Field biology of the azuki bean weevil, *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae). Seasonal prevalence and assessment of field infestation of aki-azuki, autumn variety of *Phaseolus angularis* W. *Jpn. J. Appl. Ent. Zool.* **29**: 7–13. (in Japanese with an English summary).
- SKAIFE, S. H. (1926) The bionomics of the Bruchidae. *S. Afr. Jl. Sci.* **23**: 575–588.
- SOUTHGATE, B. J. (1981) Univoltine and multivoltine cycles, their significance. In *The Ecology of Bruchids Attacking Legumes (Pulses)*. Series Entomologica, Vol. 19, Dr. Junk Publishers, The Hague, pp. 17–22.
- SOUTHGATE, B. J. (1978) The importance of the Bruchidae as pests of grain legumes. In *Ecology and Control* (S. R. Singh, ed.). H. F. van Emden and T. Ajiboa Taylor Academic Press, London, N. Y., San Francisco, pp. 219–231.
- UMEYA, K. (1981) Biology of bruchids② Suitable and unsuitable pulse as larval food. *The Insectarium* **18**(2): 4–11 (in Japanese).
- UMEYA, K., T. KATO and Y. SEKIGUCHI (1970) Studies on the comparative ecology of bean weevils. IV Tolerance to low temperature (5°C) of the five species of bean weevil infesting axuki bean. *Res. Bull. Pl. Prot. Japan* **8**: 39–50.
- UTIDA, S. (1941) Studies of experimental population of the azuki bean weevil, *Callosobruchus chinensis* (L.), I. The effect of population density on the progeny population. *Mem. Coll. Agr. Kyoto Univ.* **49**: 1–20.
- UTIDA, S. (1954) Phase dimorphism observed in the laboratory population of the cowpea weevil, *Callosobruchus quadrimaculatus*. *Jpn. J. appl. Zool.* **18**: 161–168.
- UTIDA, S. (1970) Secular change of percent emergence of the flight form in population of southern cowpea weevil, *Callosobruchus maculatus*. *Jpn. J. appl. Ent. Zool.* **14**: 71–78 (in Japanese with an English summary).
- UTIDA, S. (1971) Influence of temperature on the number of eggs, mortality and development of several species of bruchid infesting stored beans. *Jpn. J. appl. Ent. Zool.* **15**: 23–30 (in Japanese with an English summary).
- UTIDA, S. (1972) Density dependent polymorphism in the adult of *Callosobruchus maculatus* (Coleoptera: Bruchidae). *J. stored Prod. Res.* **8**: 111–126.

- WATANABE, N. (1985) Comparative studies on ecology of the azuki bean weevil, *Callosobruchus chinensis* (L.) and the cowpea weevil, *C. maculatus* (F.) (Coleoptera: Bruchidae). III. Oviposition preference for some legume seeds. House and Household Insect Pests, Nos. **25/26**: 78–85 (in Japanese with an English summary).
- YOSHIDA, T., K. SHINODA and T. OKAMOTO (1984) Life history and new wild host legume of *Callosobruchus chinensis* (L.). *Tribolium Information Bulletin*. **24**: 141.