Dry Bean Infestation and Oviposition without Feeding by a Wild Multivoltine Bean Weevil, *Kytorhinus sharpianus* (BRIDWELL) (Coleoptera: Bruchidae)\(^1\)

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A wild Bruchid, *Kytorhinus sharpianus* has several characters peculiar to stored bean pests. Its life cycle was investigated in the field and it was found to appear first on the host plant, *Sophola flavescens*, in mid June. Females oviposited on small pods just after seeds had been borne. The first generation larvae developed within the fresh growing seeds and emerged as adults in mid August. The adults soon laid eggs on matured pods. The second generation larvae fed on matured-dry beans on the standing plants and adults emerged at the end of September. Eggs were then laid directly on dry beans inside the split pods and the beans were infested by the third generation larvae. The developmental period of *K. sharpianus* larvae fed on dry host beans was studied in the laboratory under various temperature conditions. The higher the temperature was, the earlier adults emerged. Males emerged several days earlier than females. Oviposition without feeding after emergence was found in summer insects but not in wintering insects in the laboratory. The dry bean infestation of *K. sharpianus* seems particularly adapted to the life cycle of *S. flavescens*, which has the longer period from flowering to the matured-dry bean state. The process of establishment as a stored bean pest was discussed.

**INTRODUCTION**

**KIRITANI** (1956) classified Bruchid species into two groups according to infestation habits: field- and cross-types. Field-type species, such as the pea weevil, *Bruchus pisorum*, attacks only seeds in the field and never infests matured-dry beans in storage. Cross-type species, such as the azuki bean weevil, *Callosobruchus chinensis*, on the other hand, infests both immature-fresh seeds in the field and matured-dry beans in storage. Many species of the cross-type share several common characteristics such as (1) oviposition by adults without feeding after emergence, (2) oviposition directly on dry beans, (3) larval development in dry beans, and (4) multivoltinism (**KIRITANI**, 1956), which make the cross-type species the most serious pests of stored beans.

Many authors have referred to the contrast of these two infesting types among Bruchid species (**KIRITANI**, 1956; **YOSHIDA**, 1958; **UMEYA** and **KATO**, 1970; **UMEYA**, 1981; **SOUTHGATE**, 1979, 1981). Some of them have ascribed differentiation of these

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two groups to climatic origin and claimed that cross-type species might originate from tropical or subtropical regions capable of continuous breeding (Kiritani, 1956; Southgate, 1979). But the questions about what life-cycle the cross-type species had in days before human beings stored beans and how they have adapted to storage conditions remain unexplained (Watanabe, 1985).

Watanabe (1985, 1986) reported for the first time infestation of dry beans by a wild Bruchid, Sulcobruchus sauteri, and emphasized the pre-adaptation of wild Bruchids to dry beans of host plants, though the field life history of S. sauteri has not yet been studied in detail (Watanabe, 1985). Life history studies on wild Bruchids may be important to understand the process of their becoming stored bean pests. These studies, however, have just begun to attract researchers’ notice.

The present paper reports the field life history and laboratory experimental studies on a wild species of Bruchidae, Kytarinus sharpianus (Bridwell) (Fig. 1). K. sharpianus is an endemic species in Japan (Chujo, 1937) and completes its life cycle in the outdoors. The present study, however, shows for the first time that K. sharpianus possesses the four traits mentioned above peculiar to the cross-type pests of stored beans. I will explain how infestation of dry beans by K. sharpianus can be adaptive in nature, and discuss the process of establishment of stored bean pests.

FIELD OBSERVATIONS ON THE LIFE CYCLE

Field observations were carried out irregularly in 1986 and twice a month from June to early October in 1987 in the field along the border of the campus of the University of Tsukuba, Ibaraki-ken. K. sharpianus was identified according to Chujo (1937): an elongated scutellum and male comb-shaped antennae are characteristic to this species (Fig. 1).

Adult K. sharpianus first appeared in the field in mid June, when their host plant kurara, Sophora flavescens Arron (Leguminosae), blossomed (Fig. 2). Adults often crawled into the flowers and fed on the nectar and pollen. Females laid eggs on the fresh thin pods of S. flavescens just after they bore seeds (Fig. 3). Hatched larvae bored through the pod and into the beans. The number of egg shells per pod was investigated in the field in late July when all eggs had been laid by the wintering insects. Most pods
Dry Bean Infestation by a Wild Bruchid

Fig. 2. Field life cycle of *K. sharpianus* and its host plant *S. flavescens*. Dashed line indicates that time of end of the generation is unconfirmed.

![Image of a female *K. sharpianus* ovipositing on a fresh, immature pod of *S. flavescens* just after it has borne seeds. “E”: eggs deposited (June 19th, 1987).]

The first generation adults soon laid eggs on the fully developed pods of *S. flavescens* (Fig. 5). Mean number of eggs per pod increased significantly from 1.97 on July 25th to 3.57 on August 20th in 1987 ($t=4.50, p<0.001$) (Fig. 4b). At that time, some pods began to dry and the mean water content of *S. flavescens* beans was 56.1% in the still fresh-green pods and 19.6% in the matured-dry pods. Duration of oviposition by the first generation adults seemed to be prolonged since they could lay eggs on the dry pods (Fig. 2). The second generation larvae developed within the drying beans, and...
adults emerged from the pod at the end of September or in early October. A split opened in most dry pods and eggs were attached directly to the dry beans inside them by the second generation adults. Dry beans with hatched eggs were then infested by the third generation larvae.

Those beans were harvested in early October in 1987, kept at room temperature (varying from ca. 5 to 15°C) and transferred to a growth cabinet controlled at 30°C and 70% R.H. in late January. Adults emerged from them in mid February, which suggested that K. sharpianus can hibernate at the third generation larva. I have not yet confirmed, however, whether K. sharpianus hibernates in nature at either the second
generation adult or at the third generation larva, or both (Fig. 2).

MATERIALS AND METHODS

Experiment (I): Developmental periods of larvae fed on dry beans. *K. sharpianus* adults were sampled twice in the field of Tsukuba in mid June and late August in 1987. They were then cared for as laboratory stocks in plastic cups with food (sugar and dry yeast) and water according to Umeya and Shimizu (1963).

Two females were introduced from the stock into each of three petri dishes with 50 dry beans of *S. flavescens* harvested in fall 1986. Insects were removed 24 hr later. Each culture was placed in a growth cabinet controlled at either 24, 27 or 30°C, and 16L–8D cycle. The 24°C culture was founded by adults collected in mid June, and the 27 and 30°C cultures were founded by insects collected in late August. Humidity was controlled at ca. 70% R.H. or more. Bean water content was ca. 15%. Females laid eggs directly on dry beans and progeny emerged in a petri dish (Fig. 6). The number of adults emerged was checked daily.

Experiment (II): Oviposition by adults without feeding after emergence. Two males and 1 female emerged within 48 hr were collected and introduced into a petri dish with 15 dry beans of *S. flavescens*. Adults were not fed after emergence. Two replicates (Nos. 1 and 2) were founded by insects emerged in the 24°C culture in Experiment (I), and 6 replicates (Nos. 3 to 8) were founded by adults emerged from beans which were harvested in early October in 1987 and transferred to the growth cabinet (see FIELD OBSERVATIONS). They were placed in the growth cabinet controlled either at 24°C (replicates 1 and 2) or 30°C (replicates 3 to 8). Both cabinets were controlled at 70% R.H. and 16L–8D cycle. The duration of preoviposition period, the number of eggs deposited, the number of larvae that bored into beans and the number of progeny produced were investigated for each female.

RESULTS

Developmental periods of larvae fed on dry beans

Developmental periods from egg to adult emergence are summarized in Table 1. The number of emerged adults was small in the 27°C culture due to a less successful

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Male</th>
<th>Sex</th>
<th>Female</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°C</td>
<td>41.6</td>
<td>44.5</td>
<td>(22)</td>
<td>(13)</td>
</tr>
<tr>
<td></td>
<td>[38–47]</td>
<td>[41–48]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27°C</td>
<td>—</td>
<td>58.6</td>
<td>(0)</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[58–62]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24°C</td>
<td>58.3</td>
<td>65.3</td>
<td>(8)</td>
<td>(12)</td>
</tr>
<tr>
<td></td>
<td>[56–60]</td>
<td>[57–73]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No male emerged at 27°C. No. of adults emerged and range are shown in parentheses and brackets, respectively.
Table 2. Oviposition habits in *K. sharpianus* without feeding after emergence

<table>
<thead>
<tr>
<th>Source</th>
<th>Replicate no.</th>
<th>Preoviposition period (days)</th>
<th>Total no. of eggs oviposited</th>
<th>No. of larvae boring into beans</th>
<th>No. of progeny produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer insects(^a)</td>
<td>1</td>
<td>0</td>
<td>39</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1-3</td>
<td>not counted</td>
<td>not counted</td>
<td>13</td>
</tr>
<tr>
<td>Wintering insects(^b)</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5 to 8</td>
<td>---</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^a\) Adults emerged from 24°C culture in Experiment (1).

\(^b\) Adults emerged from beans which were harvested in October in 1987 and transferred to a growth cabinet in late January.

rate of boring through testa by the hatched larvae.

The higher the temperature was, the earlier the adults emerged, as shown in Table 1. Males emerged ca. 3 to 7 days earlier than females at 24 and 30°C. Invariably only one adult emerged from a bean even when plural larvae had bored into the bean.

Development of *K. sharpianus* was still dependent on the water content of the beans, though they were able to infest dry beans. Unless moisture was controlled properly in the laboratory, hatched larvae had difficulty boring through the dried testa and, even if they got through it, a much longer time was required for them to develop to adults, if they did at all. Developmental period of *K. sharpianus* was about twice as long as that of *C. chinensis* which takes, on average, 22 days for males and 23 days for females at 30°C, and 34 days for both sexes at 25°C (Ueda, 1941a, 1941b). The two sexes of *K. sharpianus* were nearly equal to *S. sauteri* taking 57 days till the first adult emergence at 24°C (Watanabe, 1985). The developmental abilities of wild Bruchids fed on dry beans may be lower than the serious stored bean pest, *C. chinensis*, however, it was surprising to find that some wild Bruchids had already acquired the ability to infest dry beans with water content of only ca. 15%.

Oviposition by adults without feeding after emergence

Oviposition habits were considerably different between the two adult sources in Table 2. Using summer insects (replicates 1 and 2), the first oviposition was seen a few hours after introduction in replicate 1, while the female in replicate 2 had not laid eggs after 24 hr. Female 1 laid 2 eggs on most beans and female 2 oviposited only 4 eggs during the first 4 days. Eventually, as shown in Table 2, female 1 laid 39 eggs in total and produced 7 progeny. Female 2 produced 13 progeny though the final number of eggs was not counted. *K. sharpianus* summer insects thus could lay matured eggs without feeding after emergence and had only a short preoviposition period, if any at all.

On the other hand, oviposition without feeding was seen in only 2 replicates out of 6 in wintering insects (Table 2). Furthermore, females 3 and 4, which could lay matured eggs, had a long preoviposition period of 10 days or more and had laid only a few eggs by the end of their life. The temperature (30°C) of the growth cabinet was not believed to have had a detrimental effect on reproduction of wintering adults,
because wintering females which were fed water and sugar laid more than 50 eggs after preoviposition period of about one week.

The physiological mechanism explaining the difference in wintering insects having long preoviposition period and needing to feed after adult emergence in order to actively reproduce, and summer insects not requiring this is yet unknown. It should be confirmed by further experiments whether experiencing cold temperature at the larval stage causes an adult dependence on feeding to begin active reproduction. SHINODA (pers. comm.) also observed that even *C. chinensis* showed a preoviposition period if they had experienced cold temperature at the larval stage.

**DISCUSSION**

*Adaptation of dry bean infestation by K. sharpianus to the life cycle of S. flavescens*

Three and a half months from flowering in mid June to matured-dry beans on the standing plants at the end of September in *S. flavescens* may be much longer than in other wild legume plants such as kuzu, *Peularia lobata*, and nemu, *Albizzia julibrissin*, available to univoltine wild Bruchid species. If larvae could feed not only on immature-growing seeds but also infest matured-dry beans, they could establish two generations on the standing host plant. Additionally, oviposition directly on dry beans could produce the third generation larvae in October.

Judging from the developmental period of *K. sharpianus* under the three temperature conditions in Table 1, three and a half months from mid June to the end of September may be slightly insufficient for two generations on the standing host plants. But real developmental rate in the field is probably faster than under the present experimental condition because of higher water content in the beans on the standing plant throughout a season. Those three and a half months seem to be enough for *K. sharpianus* to realize two generations on the host plants in the field.

Short or no preoviposition period and oviposition without feeding after emergence may be another advantage in that it is difficult to find flowering plants at the end of a season. *K. sharpianus*, of course, elongated their life span (and laid more eggs) with feeding. In stock cultures founded for Experiment (I) with food and water, adults lived more than 50 days. So, the taking of food before the first oviposition by the wintering insects in mid June (field observations) plays an important role in their laying as many eggs as possible by the end of their lives.

The abilities to infest dry, hardened beans and oviposit directly on dry beans inside the split pods are of great advantage to utilize host seeds left unutilized by previous generations. The dry bean infestation by *K. sharpianus* seems adaptable to the life cycle of *S. flavescens*. It is remarkable that a wild Bruchid has already acquired an ability to infest dry beans. The infestation ability on matured-dry beans on the host plant in the field may be a pre-adaptation to the infestation of stored beans, and will be reinforced during the adaptation process in storage with lower moisture.

*Process of establishment as a stored bean pest*

Several entomologists have divided Bruchids into two infestation types: the field vs. cross types (KIRITANI, 1956), the outdoor vs. indoor types (UMEYA, 1981), and the field vs. storage species (SOUTHGATE, 1979). But the life cycles of the cross-type Bruchids in the days before human beings stored beans and their adaptive process to the stored
beans still remain unexplained. Watanabe (1985, 1986) claimed that the following three abilities are needed for Bruchids to produce continuous generations in storage: (1) reproduction without taking any food in the adult stage, (2) oviposition on hardened seeds or pods, and (3) larval development in hardened seeds. He reported that a wild Bruchid, $S. sauteri$ had the latter two abilities, and emphasized the importance of preadaptation to the host dry beans in the process of becoming established as a stored bean pest (Watanabe, 1985).

Furthermore, Southgate (1981) suggested that multivoltine life cycles may be a key character in establishing these types as stored bean pests. Multivoltinism appears closely related to the hibernating life stage. Though many wild univoltine Bruchids hibernate at the adult stage, $C. chinensis$ larvae in the author's laboratory were able to tolerate cold temperature at $3^\circ C$ for several months. In $K. sharpianus$, though the second generation adults, which emerged earlier at the end of September or in early October, began oviposition and produced the third generation larvae, the adults which emerged later in mid or late October might enter into hibernation without oviposition. The hibernating life stage of $K. sharpianus$ may be flexible, not fixed, as is true of $C. chinensis$. A flexible life stage to combat winter or cold temperatures seems advantageous for cross-infestation both in storage and in the field. Thus, I propose the following to the above three necessary conditions by Watanabe (1985) as characteristics advantageous for the process of establishment as a stored bean pest: (4) multivoltinism, (5) not fixed but flexible hibernating life stage, and (6) no or only short previposition period.

Perhaps the most serious pests of stored beans, e.g., $C. chinensis$ and $C. maculatus$, had those six characters before beans were stored by human beings. These characters must be reinforced in the process of adaptation to stored beans. The process may also be accompanied by selection for shorter generation time and the increase in fecundity per female.

Kiritani (1956) and Southgate (1979) ascribed those characteristics of cross-infestation type Bruchids to their origin in tropical or subtropical regions where continuous breeding was possible. But $K. sharpianus$ is an endemic species in Japan (Chujo, 1937). $K. sharpianus$ in the present study may be the first evidence that a wild Bruchid, even in a temperate region, has already satisfied those six conditions, though the fifth condition should be confirmed in further field studies and the sixth has so far been satisfied only in summer insects.

The present study offered a solution in the controversy over whether one or two thousand years is enough time for ancestral wild Bruchids to have evolved into stored bean pests of today. A wild species, which infests the matured-dry beans as well as the immature-fresh seeds and has the above six characters for infesting stored beans, can invade stored beans soon, if we cultivate and stock beans of its host plant variety, as suggested by Watanabe (1985, 1986). After successfully invading storage, an increase of fecundity and shorter generation time would be selected. We should study in more detail the life histories of wild Bruchid species in order to understand the invasion process of bean weevils to stored beans.

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REFERENCES


