The Influences of Food and Photoperiod on Flight Activity and Reproduction of the Bean Bug, *Riptortus clavatus* Thunberg (Heteroptera: Coreidae)

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From the results of tethered flight tests using adults of *R. clavatus* collected from field, two kinds of flight were discriminated, a short flight of within 10 min and a long flight exceeding 10 min. Under a long day condition, females which fed on 10 adzuki bean seeds flew less actively than those fed on 1 seed. Male flight activity was higher than that of females when they were given 10 seeds. Even under a short day condition, flight activity of both females and males was lower with 10 seeds supplied than with 1. When females were reared on different numbers of adzuki beans (0.5, 1, 2, 5, 10 seeds), the cumulative number of eggs laid increased linearly with an increase in food quantity. At the same time flight activity was constantly high when the food quantity was below 2 seeds, and then the activity decreased with more than 5 seeds. Five days after emergence, the food was removed and the flight activity of females became higher than those of fed, control females.

INTRODUCTION

Migration in insects is regarded as an adaptation to colonizing in available habitats (Johnson, 1969; Dingle, 1972). Southwood (1962) indicated that migration often occurred in insects living in temporary habitats. Some insect species feed on plant seeds which are generally a highly variable resource in space and time. The high flight activity of seed-feeding bugs, therefore, is thought to be attributable to fluctuation in the abundance of the resource. Several experiments concerning the flight activity of seed bugs have been carried out (Dingle, 1965, 1968, 1972, 1978; Dingle and Arora, 1973; Caldwell, 1974; Solbreck and Pehrson, 1980). The flight activity of the ligaed bug, *Oncopeltus fasciatus* was examined by the tethered flight technique and factors shown to it were the age of the bug (Dingle, 1965), photoperiod and food conditions (Dingle, 1968).

The coreid bugs, *Riptortus* spp. are distributed throughout the world except for the New World, and are considered pests of grain legumes in India (Visalakshi and Nair, 1976), New Guinea (Gange, 1980), and Nigeria (Aina, 1975). *R. clavatus* is a pest of soybean in Japan. This bug can be reared easily in a laboratory by supplying dry soybean seeds and water. Its development under various conditions has been examined (Kidokoro, 1978), however, no one has studied its flight activity and reproduction. Factors affecting the flight activity of this bug are important to know its life history.
patterns and its pest status. The present study focuses on some characteristics of the flight activity in relation to reproduction and diapause.

**MATERIALS AND METHODS**

First, flight activity of bugs collected from a field was measured by the tethered flight technique as will be mentioned later. The bugs were collected in Kurama, Kyoto on June 20 and July 15 in 1981.

For other experiments, bugs were reared in the laboratory. Those used in the experiments below were offspring of the females collected in Kurama, Kyoto in 1981, and they were reared in plastic containers (8 cm high, 10 cm diameter). In all experiments, five nymphs or one adult were introduced into each container. Either dry soybean seeds (*Glycine max*) or dry adzuki bean seeds (*Phaseolus angularis*) were supplied as food and were replaced every other day. Water was provided from a glass tube with a cotton plug, and a mass of cotton wool was supplied for oviposition.

For the experiment to examine the effects of photoperiod on flight activity and body weight, bugs were reared from the egg stage under either a 16L8D or 11L13D, 27.5°C environmental regime. Dry adzuki bean seeds were provided as food. After emergence, adults in each photoperiod were divided into two groups; one group was provided with ten seeds while the other was provided with one seed. Flight duration and body weight were measured daily.

To examine the effects of relative food shortage on flight activity and egg production, bugs were reared at different levels of food abundance, i.e., 0.5, 1, 2, 5 and 10 adzuki bean seeds per two days.

Flight activity was measured using a modified version of the tethered flight technique of Okubo (1973). The pronotum of each bug was tipped by a toothpick with nail enamel and its legs were supported by a finger until the beginning of flight. To initiate flight, the finger was quickly removed. The flying bug was then placed in front of a low-speed fan in a chamber and its continuous flight duration was timed. The flight tests were performed at 27.5°C.

**RESULTS**

*Flight activity in field populations*

Figure 1 shows the flight activity of bugs collected from Kurama, Kyoto in 1981. Overwintered adults of *R. clavatus* began to appear in the field on June 15, and females began to lay eggs on June 19, 1981. Newly emerged adults were found in late July (Natuara, unpublished). Accordingly, both groups (A and B) of adults in Fig. 1 were overwintered ones. It is considered that adults collected on June 20 (A) were in pre-reproductive stages, but most of those on July 15 (B) were in post-reproductive stages. The flight activity of A was higher than that of B, suggesting that the start of oviposition represses adults flight activity. The percentage of bugs flying over 4 min was much lower in the A females, while it was as high as 80% within 10 min in the males and thereafter decreased. A similar trend was observed in the B bugs though the percentage was less than that of A.

This fact suggested that there were three kinds of flight, i.e. a shorter flight of less than 4 min, an intermediate flight of 4 to 10 min and a longer flight over 10 min. In
Fig. 1. Flight activity in tethered flight tests of overwintered adults collected in Kurama, Kyoto in 1981. Each dot indicates the percentage of individuals which flew for the time indicated. A: adults collected on June 20. B: adults collected on July 15. ●: female, ○: male.

Table 1. Influences of food and photoperiod on mean longevity of female adults after emergence (27.5°C)

<table>
<thead>
<tr>
<th></th>
<th>Food given</th>
<th>No food given</th>
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<tr>
<td></td>
<td>$\bar{x}$±s.d.</td>
<td>$\bar{x}$±s.d.</td>
</tr>
<tr>
<td>16L 8D</td>
<td>50.28±23.0</td>
<td>10.1±1.3</td>
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<tr>
<td>11L 13D</td>
<td>$&gt;82.9^a$</td>
<td>20.5±5.4</td>
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</table>

* 64% of females were still surviving on 120th day when the experiment ended.

this paper, the short and long flights are conveniently divided at flight durations below and above 10 min for both sexes. Furthermore, all flyers in the following discussion refer exclusively to individuals which flew more than 1 min.

Effects of photoperiod and food quantity on flight activity and body weight

In R. clavatus, ovaries of females did not develop under 13L 11D in the Tohoku district (KIDOKORO, 1978). In Kyoto, the critical photoperiod of adult diapause was between 13L 11D and 14L 10D (NUMATA and HIDAKA, 1982).

Table 1 shows the influence of photoperiod and food on the mean longevity of females after emergence. Under the long day condition, females supplied with food survived for 51 days but without food supply, they died within 10 days. Under the conditions of a short day with food supplied longevity elongated to 83 days or more.

Figure 2 shows daily changes in the flight activity of the bugs supplied with either 1 or 10 adzuki bean seeds under a long day condition (16L 8D). Females which fed either on 1 or 10 seeds began to lay eggs before the peak of the long flight, though many short flights occurred before egg laying when they were fed only 1 seed. Table 2 shows the difference in percentages of flyers by sex and between food conditions. Both the males and the females flew actively when 1 seed was supplied, but were less active.
Fig. 2. Effects of the amount of food on flight activity of bugs reared under 16L:8D photoperiod. One and 10 adzuki bean seeds were supplied, respectively. (27.5°C) ●: % of all flyers, ○: % of long flyers (>10 min). Arrows indicate the time that 50% females began to lay eggs.

Table 2. Effect of food quantity on flight under 16L:8D photoperiod

<table>
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<tr>
<th>Compared pair</th>
<th>&gt;1 min</th>
<th>% flying &gt;10 min</th>
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<tr>
<td>♀ 10 seeds</td>
<td>☚</td>
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<tr>
<td>♀ 1 seed</td>
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<td>♀ 1 seed</td>
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Student's t-test of arcsin transformed data from Fig. 2. Significant levels; ☚: not significant,
+: p<0.05, ☚+: p<0.01.

when fed 10 seeds. Under the restricted food condition (1 seed), females flew as actively as males, while with the 10 seeds they were less active than males.

Figure 3 shows the daily flight activity under the short day condition (11L:13D) with the two types of feeding. Both the males and the females flew actively when 1 seed was supplied, but were less active when fed on 10. Under the short day condition, no females laid eggs within 120 days after emergence. Differences in the percentages between sexes and food conditions are shown in Table 3. Table 4 shows the percentage comparison between long and short day conditions. Males were active regardless of food under a long day condition (Fig. 2), but they were quite inactive when 10 seeds were supplied (Fig. 3) under the short day condition. With enough food, the percentage difference between the short and long day conditions was significant at the 5% level (Table 4).

Daily changes in body weight of the bugs which fed on 10 seeds under both conditions are shown in Fig. 4. The body weight of females increased during the first 15 days after emergence under either condition. On the other hand, the weight of the males never increased under the long day condition, though with the short day, it increased rapidly as the females did.
Fig. 3. Effects of the amount of food on flight activity of bugs reared under 11L13D photoperiod. One or 10 adzuki bean seeds were supplied, respectively. (27.5°C)

\( \bullet \): % of all flyers, \( \bigcirc \): % of long flyers (>10 min).

Table 3. Effect of food quantity on flight under 11L13D photoperiod

<table>
<thead>
<tr>
<th>Compared pair</th>
<th>&gt;1 min</th>
<th>&gt;10 min</th>
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<tr>
<td>( \varphi ) 10 seeds ( \varphi ) 1 seed</td>
<td>++</td>
<td>++</td>
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<tr>
<td>( \sigma ) 10 seeds ( \varphi ) 10 seeds</td>
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<td>( \sigma ) 10 seeds ( \sigma ) 1 seed</td>
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<tr>
<td>( \varphi ) 1 seed ( \sigma ) 1 seed</td>
<td>+</td>
<td>-</td>
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Student's t-test of arcsin transformed data from Fig. 3. Significant levels; -: not significant, +: \( p<0.05 \), ++: \( p<0.01 \).

Table 4. Comparison of flight activity between 16L8D and 11L13D photoperiod

<table>
<thead>
<tr>
<th>Food offered</th>
<th>&gt;1 min</th>
<th>&gt;10 min</th>
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<tr>
<td>( \varphi ) 10 seeds</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>1 seed</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>( \sigma ) 10 seeds</td>
<td>++</td>
<td>++</td>
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<tr>
<td>1 seed</td>
<td>-</td>
<td>-</td>
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Student's t-test of arcsin transformed data from Fig. 2 and 3. Significant levels; -: not significant, +: \( p<0.05 \), ++: \( p<0.01 \).

Effects of food quantity on fecundity and flight activity

The flight activity of adults which were supplied with different numbers of dry adzuki bean seeds (0.5, 1, 2, 5 and 10 every two days) was measured on the 10th day after their emergence, and the daily number of eggs laid by females was counted for 30 days.
Figure 5 shows the relationship between food quantity and egg production, and between food quantity and flight activity. The cumulative number of eggs laid for 30 days increased linearly with an increase in food quantity, and the proportion of all flyers was constant to as high as 80% below 2 seeds, then decreasing rapidly.

Further experiments were carried out to determine whether the bug is flexible in its flight activity during its life span if the food resource deteriorates. The first group of bugs was fed on enough a sufficient number of dry soybean seeds for 5 days after adult emergence; thereafter they were starved. The second group was fed for 10 days and
then starved. As a control, the third group was fed throughout the period. The flight activity of these bugs was measured every day (Fig. 6). When the food was removed on the 5th or 10th day after emergence, the flight activity became greater than that of the fed control group. A significant difference ($p<0.001$) was seen between the means of two percentages of flyers in both the 5 day feeding group and the control, and the 10 day feeding group and the control ($t$-test).

**DISCUSSION**

Insects living in changing environments cope with uncertainties in their habitat by migration and diapause. When all habitats change simultaneously, diapause is efficient, but when each habitat changes asynchronously, migration is more efficient (GADGILL, 1971). Do the traits of flight activity and diapause of *R. clavatus* agree with this general discussion? In summer, patchily distributed leguminous plants bear seeds asynchronously. It is profitable for adult bugs to migrate from one host plant patch to a new one when the former deteriorates. In winter, simultaneous deterioration of all patches makes it impossible for the insects to colonize anywhere. However, the flight activity of *R. clavatus* was influenced by food availability under a short day condition as well as under a long day condition. What is the meaning of such adaptation?

Hibernating bugs need to store much energy in order to survive the winter. This is indicated from the fact that body weight increases for the first 15 days after adult emergence (Fig. 4). Diapausing adults live longer than non-diapausing ones, even if no food is provided after emergence (Table 1). The critical photoperiod at which diapause is induced in Kyoto is 13L.11D–14L.10D (NUMATA and HIDAKA, 1982). It corresponds to the day length of late August in Kyoto, but *R. clavatus* is still active there until October because the temperature is high enough for its developmental metabolism. Adults which emerge from September to October continue to feed on leguminous seeds without oviposition. The bugs have to use local patchily distributed habitats during the pre-diapausing season. Consequently, the dispersal tendency in relation to food conditions may be kept even under a short day condition.

So long as the food condition remained good, little flight occurred in *Neocoryphus bicrucis* (SOLBRECK and PEHRSOHN, 1980). This tendency was also shown here by *R. clavatus*. Meanwhile, *Oncopeltus fasciatus* (DINGLE, 1965) and *Hippodamia convergens* (RANKIN and RANKIN, 1980) proved to have a peak of flight activity at the post natal period even if the food condition was good. The latter two species may migrate obligatorily during the pre-reproductive period.

The flight activity tested by the tethered flight method is considered to reflect the colonizing behavior in the fields, and the measurement of flight activity of adults collected from the field supported this. Before colonizing a new habitat, it is expected that the insects fly actively because of their starvation condition. The data (Fig. 1) indicates that the long flight activity was higher on June 19 when overwintered females were in a pre-reproductive stage than on July 15 when they were in a reproductive stage. This agrees with the results of tests on the relation between flight activity and food quantity.

Under an experimental condition, starvation triggers active flight in *R. clavatus* even after the start of egg laying. Similar results were obtained for *N. bicrucis* (SOLBRECK and PEHRSOHN, 1980). For seed-feeding bugs, the generation time is gen-
erally longer than the period for which the food resource remains relatively suitable, or \( \tau/H \) is high (Southwood, 1975). Under such condition, after colonizing in a location, the quality of the habitat often deteriorates. Accordingly, flexibility to change flight activity is necessary to use such a temporary resource as food.

Flight activity in the male was higher than that in female under a restricted food condition. This may be due to the need for males to continue random flights to search for females. A high incidence of short flights in males is also reported in *N. bicrucis* (Solbreck and Pehrson, 1980).

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REFERENCES


