Simulations of the Population Changes of *Lycosa* in the Paddy Field

(Lycosidae: Lycosa)

For the purpose of establishing integrated control programmes of the green rice leafhopper (GRL), *Nephotettix cincticeps* Uhler (Hemiptera: Deltocephalidae), the role of *Lycosa* as a controlling factor of GRL has been evaluated quantitatively by the sight count method (Kiritani et al., 1972) and by computer simulations (Sasaba et al., 1973; Sasaba and Kiritani, in press). An analytical study to make clear the mechanisms of population regulation of *Lycosa*, however, remains unsolved, though the population growth of *Lycosa* follows a logistic curve with a fairly good fitness (Sasaba et al., 1973). In this paper, we intend to simulate the population changes of *Lycosa* with reference to their density effect and relative abundance of GRL to *Lycosa*.

The numbers of GRL (nymphs and adults) and of *Lycosa* per hill were counted by naked eyes from late June to early October at about weekly intervals for 6 years, i.e. 1968–1973, in an experimental paddy field covering an area of 20 × 10 m², where rice plants were grown at intervals of 60 cm for ease of census. Based on the data in 1970, 1971 and 1972, we evaluated the density effect on the rate of population changes of *Lycosa*. The number (N) of *Lycosa* per hill on *t* was obtained by the three running average: \( \bar{N}_t = (N_{t-i} + N_t + N_{t+i})/3 \), where \( i \) referred to the interval of two consecutive censuses (about 7 days). The daily rate of population changes of *Lycosa* (R) can be calculated by the following formula:

\[
R_t = (\bar{N}_{t+i} - \bar{N}_t)/(i \cdot \bar{N}_t) \tag{1}
\]

\( R_t \) was plotted against \( \bar{N}_t \) (Fig. 1). The data after August 20 were discarded in Fig. 1 to avoid inclusion of the effect of food shortage on *Lycosa* population (e.g. cannibalism etc.) (Kawahara et al., 1974). A regression line between \( \bar{N}_t \) and \( R_t \) was as follows:

\[
R_t = -0.0104 \cdot \bar{N}_t + 0.0846 \quad (r^2 = 0.306) \tag{2}
\]

Fitness of simulations was examined by differences between calculated values and observed ones in 1968, 1969 and 1973. For the initial numbers of *Lycosa* per hill in 1968, 1969 and 1973, 0.05, 0.20 and 1.00 were given, respectively. The figures are nearly equal to the observed numbers of *Lycosa* per hill on July 15, when appreciable invasion of *Lycosa* into paddy fields occurs.

In the first simulation (Simulation 1), the population changes in number of *Lycosa* per hill were predicted by substituting equation (2) for \( R_t \) in the following formula:

\[
(1 + R_t) \cdot \bar{N}_t = \bar{N}_{t+i} \tag{3}
\]

The deviations of calculated values (\( \hat{N}_{t+i} \)) from observed ones (\( N_{t+i} \)) were given in Table 1 by

\[
\sqrt{\frac{\sum(\hat{N}_{t+i} - N_{t+i})^2}{n}}
\]

where \( n \) referred to the number of censuses.

In the next simulation (Simulation 2), we

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2. Strictly speaking, \( R_t \) should be calculated as follows: \( \bar{N}_t \cdot (1 + R_t)^i = \bar{N}_{t+i} \). In this paper, we neglected the terms including the second and higher powers of \( R_t \), for \( R_t \) was almost always smaller than 0.1 (Fig. 1).
assessed the effect of food shortage on the population changes of *Lyosa*, based on the type of functional response reported in the previous paper\(^1\) (Sasaba et al., 1973). The degree of food shortage of *Lyosa* can be expressed by \(Y/Y_{\text{max}}\), where \(Y_{\text{max}}\) corresponds to the maximum number (0.6) of leafhoppers eaten in the proposed functional response. Under the assumption that the daily rate of population changes of *Lyosa* decreases in direct proportion to the increase of the degree of food shortage, the realized daily rate \(R_f\) of population changes of *Lyosa* could be given by:

\[
R_f = R_f' \cdot Y/Y_{\text{max}} = (-0.0104 \cdot N_t + 0.0846) \cdot Y/0.6
\]

(3)

Simulation 2 was conducted by equation (3). To perform calculations, \(X\) was given by dividing the observed number of GRL by the calculated number of *Lyosa* on the day concerned. Deviations of calculated values from observed ones are smaller in Simulation 2 than those in Simulation 1 except for 1973 (Table 1), though the calculated numbers of *Lyosa* are almost always smaller than the observed ones (Fig. 2).

The lengths of adult life under fasting conditions were about 30 and 15 days for females and males in *Lyosa T-insignita* B. et S., respectively (Miya-shita, 1969). The young nymphs just after being free from maternal care can withstand starvation for about 7 days in *Lyosa pseudoannulata* (Kawahara et al., 1974). The third step simulation (Simulation 3) involved the delayed effect of food shortage on the population changes of *Lyosa*.

To what extent the effect of food shortage on \(R_f\) should be postponed remains unknown. Here, two cases, i.e. 5 and 10 days delay, were tentatively considered. For instance, in the case of 5 days’ delay (Simulation 3-a), the calculated value of \(Y\) on the specific day was shifted ahead 5 days and substituted \(Y = 0.6\) for the \(Y\) values during the first five days. Calculated deviations are given in Table 1. In general, deviations from observed values are small in Simulations 3-a and b as compared with those in Simulations 1 and 2. The smallest deviation is obtained for 1969 by Simulation 3-a.

In conclusion, the first order of approximation of population changes of *Lyosa* is possible by the equation (3). This suggested that the density effect and the food shortage played an important part in the population growth of *Lyosa*. The

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\(^1\) The daily number of GRL attacked by an individual *Lyosa*, \(Y\), was calculated by the following equations:

- \(Y = 0.00\) \((0 \leq X < 1)\)
- \(Y = 0.20 \cdot X - 0.20\) \((1 \leq X < 4)\)
- \(Y = 0.60\) \((4 \leq X)\)

where \(X\) represented the relative number of GRL to *Lyosa*. 
Short Communications

evaluation of delayed effect of food shortage, however, has remained to be solved. Field and/or laboratory experiments which are designed to assess the delayed effect of food shortage should be conducted in the future.

REFERENCES


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Many insect species possess internal flora of microorganisms including bacteria, yeasts, etc. These specialized microorganisms are commonly referred to as symbiotes, and have long been considered to be closely related with the host physiology (Richards and Brooks, 1958; Koch, 1960; Buchner, 1965).

The present paper reports the histological observations and the population changes of yeast-like symbiotes in a life cycle of the smaller brown planthopper, *Laodelphax striatellus* (Fallén).

Insects were reared on rice seedlings under a constant condition of 25°C and 16 hr daily illumination. For histological preparations, whole insects were fixed in Bouin’s solution, washed in 90% ethanol, and dehydrated in butanol. After embedded in paraffin wax, they were sectioned at 6 μm. The sections were stained with Mayer’s hematoxylin-cosin, gentian violet, or Giemsa buffered at pH 5 with citrate buffer. For counting the yeast-like symbiotes at each stage, insects or eggs were homogenized gently with 0.8% saline solution. Using a Thoma’s hemacytometer, the number of symbiotes was calculated by the following formula:

\[ \text{Total No. symbiotes} = \frac{a(x+m)}{n \cdot v} \]  

(1)

\( a \) : number of symbiotes in \( v \).

\( m \) : total weight of insects homogenized.

\( n \) : number of insects or eggs homogenized.

\( v \) : volume of the insect homogenate sampled in the hemacytometer.

\( x \) : volume of the saline solution used to homogenize insects or eggs.

As \( x \) is much larger than \( m \), \( m \) may be neglected in eggs and 1st instar nymphs.

The yeast-like symbiotes were found in the fat body of the abdomen, but not in the other portions of insect body. They were elongated oval-shaped, and 13 μm length on an average. In the nymphs, the symbiotes were scattered in groups over the fat body. In the female adult, most of the fat body was occasionally occupied by the symbiotes (Fig. 1A). The symbiotes were also observed in the eggs.

The change of numbers of the symbiotes at successive stage of host is shown in Fig. 2. The total number of symbiotes increased steadily with development of the host. However, the number of symbiotes per μg of fresh weight of nymph was mostly constant (about 140-170/μg) during nymphal development. In the 5th instar stage, the female nymphs possessed more symbiotes than the male nymphs. After emergence, the symbiotes declined rapidly in numbers in the male adults.