FEEDING RATES OF THE RICE LEAFFOLDER, *Cnaphalocrocis medinalis* (LEPIDOPTERA: PYRALIDAE), ON DIFFERENT PLANT STAGES¹

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ABSTRACT

Feeding rates of the first three larval instars of *Cnaphalocrocis medinalis* on rice plants were significantly lower than those of the fourth and fifth instars. The first three instars consumed less than 10% of the larva's total consumption. Feeding also decreased with increasing plant age. The model, \( C_t = e^{\beta t} - 1.0 \), from hatching to day, \( t \), well described data for all the plant stages examined. Changes in the feeding rate constant, \( \beta \), were proportional to plant stages, expressed in days after sowing (DAS) and the relationship was well described by a linear model, \( \beta = 0.213 - 0.0008 \) DAS.

Key Words: *Cnaphalocrocis medinalis*, rice leaffolder, feeding rate, rice.

The rice leaffolder, (RLF) *Cnaphalocrocis medinalis* (Guenee) is widely distributed in rice growing areas in Asia and Oceania, Northeast Australia and Madagascar (Khan et al. 1988). The larvae damage plants by feeding on the leaves, resulting in patches with green tissues removed. Serious infestations of the leaffolder have been reported in China, Japan, and Korea (Wada et al. 1980, Hirao 1982), parts of India, Sri Lanka, Bangladesh, Nepal, and Malaysia (Khan et al. 1988). It has been considered a minor pest of rice (Grist and Lever 1965, Waldbauer et al. 1980), until recently increasing in importance in areas where modern high yielding varieties were grown (Bautista et al. 1984).

Research has concentrated on screening for resistance, insecticide evaluations, natural enemies, long distance displacements and alternative hosts, with only limited studies done on aspects of ecology, behavior and physiology of the pest (Bautista et al. 1984, Khan et al. 1988). Only a few studies on the direct damage of the larvae to rice plants has been conducted (Khan et al. 1988).

This study was conducted to determine the relationships between feeding and larval age at different plant growth stages and to develop models relating leaf area consumption with larval age and plant growth stages.

MATERIALS AND METHODS

Standard cultures of the RLF started from adults collected in Tanjong Karang, Malaysia (101°E longitude - 3°30'N latitude), were maintained in cages in the insectary. Sixty-day-old rice plants (var: MR-84) were introduced into an oviposition

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cage with RLF adults for 24 h. The plants were then placed into an aluminum cage (measuring 90 by 60 by 90 cm³) meshed all over with aluminum gauge (#40), except the aluminum floor, glass top and parts of the door. One day before the anticipated emergence of the various instars, the culture cages were taken into the laboratory for the experiments. The temperature in the laboratory was 25 ± 4°C with RH about 70 - 80% and natural illumination of 12 h light and 12 h darkness.

For the experiments, single plants (var: MR-84) of known age were planted in plastic cups (7 cm diam by 9 cm). Freshly emerged larvae of the various instars were introduced singly onto each plant using a wet fine camel hair brush. The plant was then placed in a cage made from mylar sheets.

After 24 h, the larvae were transferred onto another plant of the same age. The leaf area consumed by the larvae over the period was recorded by tracing it onto a strip of mylar using a fine black marker pen. This marked area was then measured by an area meter (Li-Cor LI 3000). The procedure was carried out daily until the larvae entered into the next developmental stage.

The experiments were repeated using plants of ages 40, 60, 80, and 100 days after sowing (DAS) and for all the larval instars. Each experimental set was replicated with 15 larvae.

Model Fitting

For fitting the data to the respective models, the non-linear curve fitting procedure, PROC NLIN with the DUD option available in Statistical Analysis Systems (SAS Institute 1985) implemented on an IBM 4361 Mainframe at IRRI was used. Goodness of fit may be determined by examining the mean square ratios (MSR) of mean squares for regression and residual and comparing them to the F distribution for respective degrees of freedom. Further, regression analysis using PROC REG in SAS on the linearized data were also carried out.

RESULTS

Larval Survival and Durations

There was no larval mortality when 40 DAS plants were used. The first instar larvae suffered mortality rates of 6.7%, 13.3%, and 60% when introduced onto plants of 60 DAS, 80 DAS, and 100 DAS, respectively. All second-instar larvae introduced onto 80 DAS and 100 DAS plants died after completing the instar.

Larval durations in the different instars were variable when fed on plants of different ages. The differences were, however, not significant.

Leaf Area Consumption

The total leaf area consumed per larva by first instars decreased with plant age. Larvae feeding on 80 and 100 DAS plants consumed significantly less than those on 40 and 60 DAS plants (Table 1). Similarly, for the second instar, larvae on 80 and 100 DAS plants could consume less than 20% as compared to that by larvae provided with 40 and 60 DAS plants. In the third instar, a similar decrease in leaf area consumption was also obtained.

In the fourth and fifth instars, reduction in leaf consumption was obtained, but the differences between plant stages were not significant.
Table 1: Leaf area consumed by each larval instar of *Cnaphalocrocis medinalis* feeding on different plant ages.

<table>
<thead>
<tr>
<th>Plant stages (DAS)</th>
<th>Leaf area consumed/larva (sq cm ± S.E.)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First</td>
</tr>
<tr>
<td>40</td>
<td>0.24 ± 0.15</td>
</tr>
<tr>
<td>60</td>
<td>0.20 ± 0.15</td>
</tr>
<tr>
<td>80</td>
<td>0.07 ± 0.05</td>
</tr>
<tr>
<td>100</td>
<td>0.05 ± 0.06</td>
</tr>
</tbody>
</table>

* S.E. at 95% confidence.

Leaves of 40 DAS plants were found to be most favorable to all larval instars. A total of 24.3 sq cm was consumed and 87% of this by the fourth and fifth instars. On older plants, these two instars accounted for more of the total consumption; 90%, 95%, and 96% on 60, 80, and 100 DAS plants, respectively. The total leaf area consumed by a RLF larva feeding on the respective plants was 21.1, 18.7, and 14.4 sq cm.

**Feeding Rate Models**

**Leaf area consumption/larva/day**

All the data for each instar feeding on plants of different growth stages were fitted to the model:

\[ Y_r = at^b \]  

where \( Y_r \) is the leaf area (sq cm) consumed per larva per day, \( t \) is the age of the larva in days, \( a \) and \( b \) are constants. The model fitting parameters are shown in Table 2. Except for data from the 100 DAS plants, the other three sets of data fitted the model satisfactorily (Fig. 1).

Table 2: Equation parameters of data fitted to the model relating leaf area consumed [(sq cm)/larva/day] with larval age in days. Model: \( Y_r = at^b \)

<table>
<thead>
<tr>
<th>Crop Stage*</th>
<th>Parameters†</th>
<th>Goodness of fit‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>40 DAS</td>
<td>0.0030 (0.0014)</td>
<td>2.5652 (0.1756)</td>
</tr>
<tr>
<td>60 DAS</td>
<td>0.0025 (0.0010)</td>
<td>2.5421 (0.1378)</td>
</tr>
<tr>
<td>80 DAS</td>
<td>0.0022 (0.0010)</td>
<td>2.5138 (0.1623)</td>
</tr>
<tr>
<td>100 DAS</td>
<td>CONVERGENCE NOT MET</td>
<td></td>
</tr>
</tbody>
</table>

* DAS = Days after sowing
† Numbers in parentheses represent standard errors at 95% confidence.
‡ MSR = Mean square ratio of mean squares for regression and residual. VR = Variance ratio of regression analysis using linearized data. ** = Indicates significance at \( P = 0.01 \).
Fig. 1. Leaf area consumed/larva on each day of the larval stage feeding on plants of different stages. Data represented as means with S.E. at 95% confidence. The expected curves are obtained from the model in equation 1 and parameter values in Table 2.
Age-specific leaf area consumption

For each replicate, the leaf areas consumed/larva/day were cumulated. The data sets were fitted to the model:

\[ C_t = \exp(\beta t) - 1.0 \]  

where \( C_t \) is the cumulative amount of leaf area consumed in sq cm at day \( t \), and \( \beta \) is the feeding constant. The model fitting parameters are shown in Table 3. In all cases, the data fitted the model significantly (Fig. 2).

Table 3. Parameters of data fitted to the model in Equation 2 relating the total leaf area consumed (sq cm)/larva with larval age in days at different plant stages. Model: \( C_t = e^{\beta t} - 1.0 \)

<table>
<thead>
<tr>
<th>Plant Stage*</th>
<th>Parameters †</th>
<th>Goodness of fit‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta )</td>
<td>MSR</td>
</tr>
<tr>
<td>40 DAS</td>
<td>0.1815 (0.0007)</td>
<td>6205**</td>
</tr>
<tr>
<td>60 DAS</td>
<td>0.1692 (0.0007)</td>
<td>7673**</td>
</tr>
<tr>
<td>80 DAS</td>
<td>0.1536 (0.0009)</td>
<td>3487**</td>
</tr>
<tr>
<td>100 DAS</td>
<td>0.1360 (0.0011)</td>
<td>2024**</td>
</tr>
</tbody>
</table>

* DAS = Days after sowing
† Numbers in parentheses represent standard errors at 95% confidence.
‡ MSR = Mean square ratio of mean squares for regression and residual. VR = Variance ratio of regression analysis using linearized data. ** = Indicates significance at \( P = 0.01 \).

Since the feeding rates of the first three instars are significantly lower than the fourth and fifth instars, an alternate approach is to express the rates using two linear models. The data for the first 10 d were fitted to a linear model, \( Y_t = m_1 t \). Data from day 11 to 19 were fitted using another linear model, \( Y_t = m_2 t + K \). The parameters of fit are shown in Table 4. The data fitted the two models in all cases, including those from 100 DAS plants which did not provide satisfactory fit using the exponential model.

Table 4. Parameters of data fitted to two linear models relating the total leaf area consumed (sq cm)/larvae with larval age at different plant stages.

<table>
<thead>
<tr>
<th>Plant Stage (DAS)*</th>
<th>0-10 days</th>
<th>11-19 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model: ( Y_t = m_1 t )</td>
<td>Model: ( Y_t = m_2 t + K )</td>
</tr>
<tr>
<td></td>
<td>( m_1 ) ± S.E.</td>
<td>( R )†</td>
</tr>
<tr>
<td>40 DAS</td>
<td>0.2249 ± 0.0082</td>
<td>0.68**</td>
</tr>
<tr>
<td>60 DAS</td>
<td>0.1420 ± 0.0050</td>
<td>0.69**</td>
</tr>
<tr>
<td>80 DAS</td>
<td>0.0571 ± 0.0026</td>
<td>0.58**</td>
</tr>
<tr>
<td>100 DAS</td>
<td>0.0407 ± 0.0014</td>
<td>0.69**</td>
</tr>
</tbody>
</table>

* DAS = Days after sowing.
† \( R \) = Correlation coefficient. ** = Indicates significance at \( P = 0.01 \).
‡ VR = Variance ratio of regression analysis. ** = Indicates significance at \( P = 0.01 \).
Fig. 2. Total leaf area consumed by larvae of *Cnaphalocrocis medinalis* feeding on plants of different stages. Data are represented by means and S.E. at 95% confidence. The curves are generated from the model in equation 2 and parameter values in Table 3.
DISCUSSION

RLF larvae damage rice plants by folding and feeding on leaf surfaces. Photosynthetic tissue is removed, thus affecting yield. Grain weight is significantly reduced when four leaves per plant were damaged at heading (Heinrichs et al. 1979). Using defoliation experiments, Bautista et al. (1984) estimated the economic threshold at booting and heading stages to be 1.51 and 1.32 larvae/plant, respectively. These values were based on the mean consumption per larva of 101.2 sq cm, which was grossly overestimated. On the favorable plant age of 40 DAS, a larva could only consume 24.3 sq cm. Moreover, leaf area consumption per larva differed substantially with the plant growth stages. In the older plants, the larvae fed on < 80% of what they would on younger plants.

The model in Equation 2 provides a means to predict the leaf area consumption of the larva which has lived to a given day. This model can be utilized with an appropriate population model of the RLF to simulate damage and its effects on yield. Since it is a one-parameter model, the relationship between the parameter values with plant stages may be used to interpolate for other plant stages. This linear relationship (Fig. 3) is highly significant ($r^2 = 0.99$, $P < 0.01$) for plant stages between 40 and 100 DAS and is given as:

$$
\beta = 0.2133 - 0.0008 \text{DAS} \tag{3}
$$

where DAS is plant age in days after sowing.

In all cases, the proposed model slightly overestimates the consumption of the first three instars, but provides good estimates for the fourth and fifth instars. The alternate approach of using two linear models, however, could only provide good estimates for the first three instars, but not the fourth and fifth. Since the first three instars consume less than 10% of the total consumption, one may need only to pay attention to damage by the fourth and fifth instars. When combined, equations (2) and (3) may be used to represent the relationship between leaf area consumed by different larval instars feeding on plants of different growth stages (Fig. 4).

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Fig. 3. Relationship between the feeding rate coefficient, $\beta$, of the rice leaffolder and plant stages. Data are represented by means and S.E. at 95% confidence and the line is the linear model in equation 3.
Fig. 4  Relationship between leaf consumption, age of larvae and plant stages in the rice leaffolder.

REFERENCES CITED


