Role of Silica in Resistance to Asiatic Rice Borer, *Chilo suppressalis* (Walker), in Rice Varieties

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**ABSTRACT**

This study was conducted to test the reactions of several rice varieties to Asiatic rice borer infestation under natural field conditions, and to examine the relationship between plant silica content and susceptibility to stem borer.

Based on results from 3 different tests, the varieties could be classified into 3 groups: resistant, moderately resistant, and susceptible. Reactions to the Asiatic rice borer infestation were highly consistent, indicating that resistance was due to inherent varietal characters. A highly significant negative correlation was recorded between silica content of the stem and susceptibility to the rice borer. High silica content in the plant seemed to interfere with feeding and boring of the larvae and could cause defacing of their mandibles.

Although several studies have reported the effects of silica on rice borer susceptibility, this is the first report of varietal difference in plant silica content. The use of varieties with high silica content is a more practical and economical method of reducing rice borer infestation than applying silicate to paddy soil.

The present paper reports the results of evaluation of 3 replicate experiments. The data show that a high level of resistance is associated with high silica content in the plant. This is the first time that such a relationship has been reported.

Among the insect pests of rice plants, the Asiatic rice borer is one of the most destructive throughout Asia. The use of insecticides, despite its certain drawbacks, is the only effective method known for controlling this insect. As the pest is widely distributed and causes heavy losses in rice production, it is important that other control measures which are more permanent and have wider applicability also should be studied. The development of a rice borer-resistant rice variety is a possibility.

The feasibility of breeding rice borer-resistant rice varieties is being investigated at The International Rice Research Institute. This investigation involves screening for resistance a collection of about 10,000 lines representing most of the rice varieties of the world, and studying causes and inheritance of resistance by selecting resistant and susceptible varieties. The differences in varietal susceptibility in these tests and the effect of resistant and susceptible varieties on the rice borer was reported by Pathak (1964). Patanakamjorn and Pathak (1967) recorded the correlations between rice borer susceptibility and pertinent plant morphologic and anatomical characters.

The silica content of the plant has generally been considered to impart resistance to pests and diseases. Sasamoto (1961) recorded an increase in the percentages of total silica in rice plants when grown in a soil treated with silica gel or slag material and a parallel decrease in their rice borer susceptibility. Nakano et al. (1961) observed heavy rice borer infestation in areas where available silica content in the soil was low.

Table 1.—Rice borer infestation on a few of the varieties tested. Each figure represents average of results obtained during 3 different plantings, each planting consisting of 3 replications. International Rice Research Institute, 1964-65.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Dead heart</th>
<th>White head</th>
<th>Infested tiller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistant*</td>
<td>0.87</td>
<td>2.86</td>
<td>7.52</td>
</tr>
<tr>
<td>Yabami Montakhab</td>
<td>1.51</td>
<td>1.87</td>
<td>5.22</td>
</tr>
<tr>
<td>TCM-6</td>
<td>2.66</td>
<td>4.99</td>
<td>3.86</td>
</tr>
<tr>
<td>Chianan 2</td>
<td>2.75</td>
<td>6.80</td>
<td>7.68</td>
</tr>
<tr>
<td>Taitung 16</td>
<td>3.56</td>
<td>2.95</td>
<td>13.92</td>
</tr>
<tr>
<td>Moderately Resistant*</td>
<td>3.67</td>
<td>10.61</td>
<td>10.61</td>
</tr>
<tr>
<td>Taichung 160</td>
<td>4.49</td>
<td>5.31</td>
<td>8.94</td>
</tr>
<tr>
<td>Chianan 8</td>
<td>4.97</td>
<td>6.24</td>
<td>8.54</td>
</tr>
<tr>
<td>Chiangung 242</td>
<td>9.08</td>
<td>9.08</td>
<td>28.11</td>
</tr>
<tr>
<td>Susceptible*</td>
<td>11.90</td>
<td>9.08</td>
<td>25.10</td>
</tr>
<tr>
<td>Rexoro</td>
<td>13.10</td>
<td>4.94</td>
<td>25.10</td>
</tr>
<tr>
<td>Fortune</td>
<td>15.30</td>
<td>5.28</td>
<td>25.25</td>
</tr>
<tr>
<td>Sapan Kwar</td>
<td>16.47</td>
<td>4.31</td>
<td>32.05</td>
</tr>
</tbody>
</table>

*Classification based on the formation of dead hearts in the 3 field plantings.

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of 20 selected varieties for their consistency and degree of rice borer resistance in 3 different field planting seasons and correlations between their silica contents and their resistance to the rice borer.

MATERIALS AND METHODS.—The natural rice borer infestation on the test varieties was studied in field plantings during the dry and wet seasons of 1964 and the dry season of 1965. Each variety was transplanted in 3 replications in a randomized block design. Each replication consisted of 100 plants in 5 rows. The field was fertilized at the rate of 90-30-30 kg of N, P,O$_5$, and K$_2$O/hectare, respectively. More than 90% of the natural rice borer population during these tests consisted of Asiatic rice borer.

Observations for dead hearts were made on all the plants in a variety at 15-20 day intervals, beginning 1 month after transplanting. Records for white heads were made 10 days before harvest. Following white head counts, 10 randomly sampled hills from each plot were dissected to determine the number of infested hills and the number and species of the living larvae. The percentage of dead hearts or white heads was computed by the following formula (Oñate 1965):

\[
\bar{x} = \frac{(P\bar{n}_{dead~heart} + Q,0) \times 100}{\text{number of affected hills}}
\]

where

\[ P = \frac{\text{number of affected hills}}{\text{number of dead hearts}} \]

\[ \bar{n}_{dead~heart} = \frac{\text{number of affected hills in the plot}}{\text{number of affected hills}} \]

\[ Q = (1 - P) \]

The silica content of 5 randomly sampled hills from each plot was analyzed at 60 days after transplanting. These plants, dried in an oven at 70°C for 48 hr, were finely ground. A 2-g sample was dry ashed at 550°C in a muffle furnace and the silica content in the ash was determined gravimetrically. The data are presented as the percentages SiO$_2$ on an oven-dry basis.

RESULTS AND DISCUSSION.—Differences in Varietal Susceptibility.—There were consistent and highly significant differences in the rice borer susceptibility of the varieties tested in all 3 plantings. The average rice borer infestation on some of these varieties is presented in Table I. When the values of dead hearts, recorded 55 days after transplanting, were pooled for the 3 cropping seasons and analyzed by Duncan’s multiple range test, the varieties could be classified into 3 distinct categories: resistant, moderately resistant, and susceptible (Table 1). The F values for season difference and season × variety interaction were highly significant. The partitioning of season × variety into its various components indicated that the source of interaction was season × between groups. In the components of varietal difference, F value between groups was highly significant, indicating definite differences in the susceptibility of varieties of different groups, but the differences within each group were not significant. This fact shows that the reaction of the varieties of each group was consistent and did not change with season or intensity of insect infestation.

The preference of the moths for oviposition on certain varieties was responsible for some of these differences. This phenomenon was evident in varieties
For some varieties there was no further increase in dead hearts in the subsequent 20 days, but there was a sharp increase in others, reaching 24.5% in Fortuna. The increase in the percentage of dead hearts was slower on resistant than on susceptible varieties and the difference was found to be highly significant (Fig. 2).

There were distinct differences in the distribution of rice borer damage between varieties in all 3 field experiments. In resistant varieties, infestation was localized in small patches, indicating restricted migration of the larvae from the plants on which eggs were laid to adjacent hills. This phenomenon could have been due to the unsuitability of the plants for larval survival and development, thereby resulting in reduced larval population on resistant varieties. That such unsuitability exists has been confirmed in greenhouse studies where high larval mortality in the early instars, slow rate of growth, and low larval body weight has been recorded on resistant varieties (International Rice Research Institute 1965).

There were significant differences in the percentages of white heads which ranged from 2.9 to 16.6 on different varieties. Based on the average values of the 3 experiments, there was no correlation between the percentages of dead hearts and white heads formed on different varieties. On susceptible varieties high percentages of dead hearts generally resulted in heavy damage to the plants, thereby making them less attractive for further infestation. Furthermore, white heads are formed following only slight

![Graph](image-url)

**Fig. 2.—Relationship between plant age and the rate of development of infestation in resistant, moderately resistant, and susceptible varieties. The lines were drawn by eye fitting. IRRI. February-June 1964.**

Yabami Montakhab, TKM 6, Rexoro, and Fortuna, on which numbers of egg masses were positively correlated with percentages of dead hearts. However, in several other varieties there was no direct correlation between number of egg masses and dead hearts, e.g., Taitung 16 and Fujisaka 22 which received 17-27 egg masses but had only 2% or less dead hearts. By contrast, although an identical number of egg masses was laid on varieties Rexoro and Fortuna, they had more than 13% dead hearts. Thus, preferential oviposition was not the only factor involved in resistance.

The number of egg masses laid on a given variety is primarily a function of the moth's preference for oviposition sites, while the percentage of dead hearts resulting from a given number of eggs depends on the tolerance of a variety to rice borer damage or its suitability for larval survival and development. Such factors were suggested to be operative in varieties receiving a high number of egg masses but still showing low percentages of dead hearts. Further analysis of the data showed a highly significant positive correlation \((r = 0.724)\) between the percentages of dead hearts and the number of living larvae per plant. Therefore, in the varieties tested, resistance could not be ascribed to tolerance of infestation. Thus the nonsuitability of varieties for larval establishment and feeding, often referred to as antibiosis, was a major factor in resistance to the borers.

The development of dead heart and white head in the 20 varieties tested during the dry season (February-May) of 1964 is shown in Fig. 1. When counts were made 35 days after transplanting, percentages of dead hearts, ranging from 0.94 in Yabami Montakhab to 1.67 in Hill selection × Bluebonnet, did not differ significantly. However, in counts made 20 days later, the percentages of dead hearts ranged from 0.94 to 9.85 and the differences were highly significant. For some varieties there was no further increase in dead hearts in the subsequent 20 days, but there was a sharp increase in others, reaching 24.5% in Fortuna. The increase in the percentage of dead hearts was slower on resistant than on susceptible varieties and the difference was found to be highly significant (Fig. 2).

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![Graph](image-url)

**Fig. 3.—Correlation between silica contents of the stems and percentage of dead hearts of different rice varieties. IRRI. August-December 1964.**
larval feeding, and antibiosis factors within the plants do not become operative before the damage is caused. It is therefore likely that ovipositional preference may often play a more important role in white head formation than the antibiosis effect. It is possible also that changes within the plants make them more susceptible during later stages of growth.

It can therefore be concluded that the varieties tested differed consistently and significantly in their rice borer susceptibility. Some of these differences were found to be due to the ovipositional preference of the moths for certain varieties, while others were due to unsuitability of a variety as a larval host.

The Role of Silica as a Factor in Resistance to Rice Borers.—The plant silica (SiO$_2$) contents of varieties varied significantly. It ranged from 9.7% in the rice borer susceptible variety, Sapan Kwai, to 13.9% in the resistant variety, Yabami Montakhab, and showed a highly significant negative correlation with the percentages of dead hearts in different varieties (Fig. 3). Therefore, it was apparent that high silica contents in the rice plant rendered them less susceptible to the borers. The percentages of dead hearts and number of living larvae per hill were positively correlated ($r = 0.60$), implying that varieties with high silica content had a lower rice borer population, although silica content and the number of egg masses laid were not correlated. Therefore, higher amounts of silica present in the host plants adversely affected larval survival and reduced dead heart formation.

That high plant silica content interfered with larval feeding was confirmed by observations of the mandibles of larvae feeding on the variety Yabami Montakhab, which has a high silica content. The mandibles were severely worn, whereas those of larvae feeding on the variety Sapan Kwai, which has a low silica content, were normal (Fig. 4). Naturally, insects with worn mandibles will have low feeding efficiency.

In the rice stem, silica is deposited mostly in the epidermis, sclerenchymatous tissues, vascular bundle sheath, and along the cell walls of the parenchymatous tissues. In the epidermis, it is primarily contained in silica cells. Generally, varieties with higher silica content had more silica cells in the epidermis and a negative correlation was recorded between the number of silica cells and the percentages of dead hearts caused by the borers. However, the correlation coefficient of percentage dead hearts with the total silica contents was higher ($r = -0.88$) than with the number of silica cells in the epidermis ($r = -0.60$). A large number of silica cells in the epidermis might inhibit larvae from boring into the stem, while silica in other tissues might interfere with their feeding after they have entered the pith.

The silica cells in rice stems occur in numerous shapes: dumbbell, oblong, round, cubical, and *oryza* type (which show variations in form from a compressed dumbbell to nearly cubical, but the vertical axis is always longer than the horizontal axis) (Metcalfe 1960). In the resistant variety Yabami Montakhab, they were of *oryza* type and densely distributed; while those in susceptible variety Sapan Kwai were oblong and sparse in distribution. In *Oryza ridleyi*, which has been recorded as highly resistant to borers, they were large, dumbbell shaped, and densely distributed (Fig. 5).

![Fig. 4.—The mandibles of *Chilo suppressalis* larvae. A, the incisor region remained normal when the larvae fed on plants with a low silica content; B and C, the incisor region became worn off when the larvae fed on a high-silica-content variety Yabami Montakhab.](image-url)
Effect of Silica Content on Boring Activities of Larvae.—Sites of larval boring were studied on the high-silica-content variety Yabami Montakhab, and the low-silica-variety Sapan Kwai. Five-day-old larvae were caged separately on stem nodes and internodes, 500 larvae being confined to each part of each variety.

On the stem pieces containing only internodes, 0.4% of the larvae bored into the high-silica-content variety Yabami Montakhab, compared with 17.5% for the low-silica content variety Sapan Kwai. In cages containing only nodal parts, 71% of the larvae bored into Yabami Montakhab compared with 96% in variety Sapan Kwai. The remaining larvae did not enter the plant tissues. Thus, significantly more larvae entered stems of the variety with low silica content than those of the variety with high silica content. In both varieties more larvae bored through the nodal than the internodal area. In general, lower silica content was recorded in the nodal than the internodal areas. Furthermore, the nodal areas consist of actively growing meristematic tissues which are softer and might be preferred as larval boring sites.

These results demonstrated that high silica content in the rice plant interfered with larval boring and feeding. Silica was more effective in preventing boring in the internodal areas than in the nodal area. Since more of the emerging larvae normally bore through the nodal area, it is probable that silica plays only a limited role in rice borer resistance.

REFERENCES CITED


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J. Econ. Entomol. 60 (1) : 264. Table 1, 1st column, change Group IV treatment to read HCN, 48 oz only in 1964; + dichlorvos, 0.5 g daily.