Influence of Rice Genotypes on Folding and Spinning Behaviour of Leaffolder *Cnaphalocrocis medinalis* and Its Interaction with Leaf Damage

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Abstract: Folding and spinning characteristics of *Cnaphalocrocis medinalis* (Guen.) (Lepidoptera: Pyralidae) examined in different categories of rice genotypes viz., resistant, susceptible, hybrid, scented, popular and wild rice genotypes were significantly different. Longer leaf selection time and folding time per primary fold; shorter primary fold and whole leaf fold; lower number of binds per primary fold and whole leaf fold were recorded in resistant and wild rice genotypes. In the correlation studies, it was found that the leaf folding parameters were positively correlated to leaf folder damage whereas the leaf spinning parameters were negatively correlated. Similarly, the morphological characters differed significantly among the chosen genotypes and were related to leaffolder damage. The leaf width and total productive tillers were positively correlated to leaffolder infestation. Results also indicated that the trichome density and length, leaf length and plant height may contribute to resistance while total number of green leaves had no effect on leaffolder infestation. In the scatter plot analysis between leaf folding and spinning characters and leaffolder damage, the genotypes were separated into four groups viz., resistant (TKM 6, Ptb 33, TNAU LFR 831311, *Oryza rhizomatis* and *O. minuta*), moderately resistant (ASD 16 and CORH 1), moderately susceptible (ADT 36, Pusa Basmati and CB 200290) and susceptible (IR 36 and TN 1). The present investigation proved that the leaf morphology viz., leaf length and width, plant height and trichome density and length may play a vital role in resistance against rice leaffolder.

Key words: rice genotype; *Cnaphalocrocis medinalis*; folding and spinning behaviour; leaf morphology

Rice leaffolder, *Cnaphalocrocis medinalis* (Guen.) (Lepidoptera: Pyraustidae), is considered an important production constraint of rice in South Asia and other parts of the world. The caterpillars of this insect feed on the leaf by scraping the green matter resulting in reduced photosynthesis leading to reduction in yield (Fraenkel and Fallil, 1981; Khan et al, 1989). Large scale cultivation of high yielding varieties and the accompanying changes in cultural practices are very conducive to leaffolder infestation (Dale, 1994; Senthil Nathan et al, 2004). In addition, application of high level of nitrogen fertilizers, continuous cropping, staggered planting and non-judicious use of insecticides have been reported as causes of increased leaffolder outbreaks. The pest has been recorded to cause 63% to 80% yield loss in rice (Rajendaran et al, 1986; Muragesan and Chelliah, 1987). In this context, host plant resistance, which is relatively economical, ecofriendly and compatible with other methods of pest management, has recently become a major management strategy against leaffolder.

Of the two mechanism of resistance, namely morphological and biochemical (Dent, 1991), morphological factors can serve as defense mechanism for plants when herbivores come into contact with them. The growth, development and survival of plant-feeding insects are affected after they begin feeding on host plants possessing morphological defense characteristics (Panda and Khush, 1995). The morphological basis of resistance by host plants depends on factors such as colour, shape and size (Courtney and Kibota, 1990) and plant architecture/anatomical features such as spikelet density and the presence of awns (Watson and Dixon, 1984). The physicomorphic leaf characters may either have negative or positive influence on the pest population...
as well as their natural enemies. In rice, density of trichomes and length on leaves, leaf surface and leaf sheath compactness were associated with resistance (Israel, 1969; Roy et al, 1969). Joshi et al (1983) observed dense and long trichomes in resistant rice varieties. Ramachandran and Khan (1991) demonstrated that the trichome density on the abaxial surface of TKM-6 showed resistance to leaf folder. Lin (1993) suggested that the external diameter of the culm and the length of the third internode play a role in rice varieties showing induced resistance to *Scirpophaga incertulus*. Plant characters like plant height, productive tillers, leaf length, leaf area and leaf thickness have significant impacts on the food searching capability of rice leaf folder on rice genotypes (Islam and Karim, 1997).

Considering the growing importance of rice leaf folder across the rice growing countries there is a need to study the behavioral aspects of leaf folder on diverse rice genotypes. Dhaliwal et al (1979) reported that *C. medinalis* prefers fine grain and scented varieties as compared to the short, medium duration and non-aromatic varieties. It thrives on high yielding susceptible rice cultivars but fails to feed, grow, survive and reproduce adequately on resistant rice plants (Sexana and Khan, 1991; Khan et al, 1989). Cultivars with longer and broader leaves recorded more leaf folder damage (Chalapathi Rao et al, 2002). Several donors such as TKM-6, WC-1263, Ptb-33, GEB-24 and Muthumanikam are known to possess multiple resistances to rice leaf folder (Khan and Joshi, 1990). The development and use of resistant varieties can be a better option to reduce the dependence on insecticides and also to obtain sustainable rice production. Unfortunately, all the existing commercial rice varieties are susceptible to rice leaf folder and it has become highly imperative to find out the resistance sources in rice germplasm (Rehman et al, 2005). Consequently, continuous effort is needed to identify rice cultivars with high levels of resistance against this pest. Currently, information on host plant factors as affecting the spinning and folding behavior of rice leaf folder on different groups of rice genotypes is scanty (Fraenkel and Fallil, 1981; Fraenkel et al, 1981). With this in view the present investigation was carried out to study the folding and spinning behavior of *C. medinalis* in relation to morphological features of rice genotypes which in turn will help to identify resistance genotypes for rice breeding and production in future.

### MATERIALS AND METHODS

#### Plant materials

The seeds of susceptible varieties (TN 1 and IR 36) (Khan et al, 1989), moderately resistant variety (ASD 16), resistant varieties (TKM 6, Ptb 33 and TNAU LFR 831311) (Nadarajan and Nair, 1983; Rajendran et al, 1986; Rekha et al, 2001), scented variety (Pusa Basmati), hybrid (CORH 1), popular variety (ADT 36) and wild rice genotypes (*O. minuta* and *O. rhizomatis*) (Alisha et al, 2001) were collected from Paddy Breeding Station, TNAU, Coimbatore. Seeds were sown in mud pots (10 cm × 12 cm). Rooted slips of the wild rice genotypes were planted in tubular mud pots (80 cm × 80 cm) and grown in green house. The genotypes at the maximum tillering phase were collected and used for further experiments. The main characteristics of the cultivated and wild genotypes used in the study were presented in Table 1 (Uthamasamy, 1985; Heinrichs et al, 1985; Vaughan, 1989; Veluchamy et al, 1990; Khan and Joshi, 1990).

#### *C. medinalis* culture

*C. medinalis* was cultured according to Waldbauer and Marciano (1979). Field-collected adults were released in oviposition cages (50 cm × 50 cm × 75 cm) inside which 30 d potted plants of TN 1 and honey solution (20%) kept as adult feed. The eggs were collected daily and placed on moist filter paper in Petri dishes. Later, the newly hatched first instar larvae were transferred singly to the axils of rice plants with a fine pointed camel hair brush. The larvae fed on the leaves by scraping the green matter. Larvae of suitable size (the second and third instar) were transferred to the test rice genotypes for behavioural studies.

#### Folding and spinning characteristics of *C. medinalis*

Folding and spinning characteristics of the third instar *C. medinalis* were observed on rice genotypes at the maximum tillering stage (Islam and Karim, 1997). Twenty-day-old seedlings of the selected rice genotypes were planted in mud pots (15 cm × 10 cm) and kept in long iron trays (1.50 m × 0.75 m) containing water. A single tiller was retained from each pot at the time of the maximum tillering stage and a third instar larva was placed on a leaf and left sufficient time to fold. Observations were made on the time taken for leaf selection, number of binds to make the primary fold (several cm long fold made between
leaf selection and first break for long rest), number of head swings from one edge to other of the leaf to make each bind and time taken for construction of primary fold. The sequence of binds was sketched and the length of the primary fold measured by standard scale. After recording the measurements, the pots were covered with Mylar film cage and left overnight. The length of folds was again measured 24 h after release of larvae to determine the extension of the primary fold. The experiment was replicated 20 times.

**Antixenosis for leaffolder resistance**

Tests were carried out to assess the spinning and folding ability of larvae on selected rice genotypes by leaf bit method. About 6 cm leaf bit from the center of the third leaf was placed in a Petri dish, lined with moistened filter paper and a single second instar larva was released on the leaf bit. The time taken for initiation of spinning and length of rolled leaf were recorded in an hour. The experiment was replicated 20 times in a completely randomized design. The test was then repeated with the third instar larvae.

**Assessment of leaffolder damage**

Potted plants of rice genotypes at peak vegetative phase were placed in an iron tray (1.50 m × 0.75 m) containing water and covered with Mylar film cage after introducing 10 pairs of adults for oviposition. The experiment was replicated 10 times with each replication consisting of two plants per pot. After 25 d, leaffolder damage on individual rice genotypes was recorded following the formula given below.

Leaffolder damage = No. of damaged leaves per five hills / Total number of leaves per five hills × 100

**Plant morphological characters**

The morphological basis of resistance was assessed during peak vegetative stage of chosen rice genotypes. The total productive tillers per hill, number of green leaves per hill, plant height (cm), leaf length (cm) and width (cm) were observed from 10 randomly selected hills in each replication and correlated to leaffolder damage. Similarly, the trichome density (mm²) and length (µm) on the leaf were estimated as the method described by Maite et al (1980) and correlated to leaffolder damage.

**Statistical analysis**

Data obtained were statistically analyzed in a completely randomized design and different parameters observed in the experiments were subjected to analysis of variance (ANOVA) (SAS Institute, 1996). Data of larval folding and spinning characters and morphological characters were correlated to leaffolder damage. The same data set was also subjected to scatter plot analysis to categorize the genotypes into different groups (Singh and Chaudhury, 1979).

**RESULTS**

**Characteristics of selected rice genotypes**

The description of cultivated and wild *Oryza* species with reference to type of spikelets and panicles is furnished in Table 1. Medium and moderately dense...
types of panicles were observed in the resistant rice genotypes viz., TKM 6, Ptb 33 and TNAU LFR 831311. On the contrary, panicles were long compact types in popular variety ADT 36 and moderately resistant variety ASD 16, and short compact types in susceptible genotypes TN 1 and IR 36. Long and slender types of panicles were observed in scented varieties viz., Pusa Basmati and CB 200290 and hybrid genotype CORH 1. The panicles of *O. minuta* and *O. rhizomatis* were semi-open and open type, respectively.

**Leaf folding behaviour of *C. medinalis***

Leaf folding characteristics including leaf selection time, primary fold length, binds per primary fold, binds per fold and fold length after 24 h are showed in Table 2. The time taken for leaf folding varied from (1.4 ± 0.1) min to (4.6 ± 2.6) min after inoculation on genotypes. Leaf selection time was prolonged in resistant genotypes such as Ptb 33, TKM 6 and TNAU LFR 831311 as compared to scented genotype Pusa Basmati and susceptible genotype TN 1. Significant differences were observed in the primary fold length formed by larvae among selected genotypes which ranged from (2.6 ± 0.1) cm to (6.3 ± 0.2) cm. The resistant genotypes Ptb-33, TNAU LFR 831311 and TKM 6 registered shorter primary fold length than in susceptible genotype IR 36 and TN 1. Similarly, the number of binds formed by the larvae to make primary fold was lower in *O. rhizomatis*, *O. minuta* and TKM-6 compared to susceptible genotype TN 1. The number of binds involved per fold by *C. medinalis* differed among the selected genotypes and ranged between 6.0 ± 0.4 and 14.3 ± 1.1. The binds per fold were lower in resistant genotypes Ptb 33, TKM 6 and wild genotype *O. rhizomatis*, whereas it was higher in scented, hybrid and susceptible genotypes. Likewise, length of fold varied from (4.7 ± 0.3) cm to (11.0 ± 0.4) cm among the chosen genotypes. The fold length was shorter in TKM 6, Ptb 33 and *O. rhizomatis* than in susceptible genotype TN 1.

**Leaf spinning behaviour of *C. medinalis***

*C. medinalis* spinning characteristics such as head swings, binds and folding time per primary fold and binds per fold varied significantly among the diverse groups of rice genotypes (Table 2). Number of larval head swings per primary fold ranged from 286.0 ± 17.9 to 838.0 ± 23.4. Resistant genotypes TKM 6, Ptb 33 and TNAU LFR 831311 had the highest number head swings per primary fold compared to susceptible genotypes IR 36 and TN 1. Similarly, number of larval head swings per bind varied from 42.0 ± 6.2 to 131.0 ± 7.9 among the selected genotypes. It was significantly higher in TKM 6 and *O. rhizomatis* (131 head swings per bind) than in susceptible genotypes. The time taken for whole leaf folding by *C. medinalis* differed significantly among genotypes which ranged from (8.4 ± 1.6) min to (21.7 ± 3.9) min. The larval leaf folding time was prolonged in the resistant genotypes TNAU LFR 831311, TKM 6 and wild rice genotype *O. minuta* whereas it was shorter in IR-36.

**Correlation between folding and spinning characters and leaffolder damage**

*C. medinalis* folding and spinning characters were correlated with leaffolder damage (Fig. 1). Primary fold (*r* = 0.86, *P* < 0.05), fold length per 24 h (*r* = 0.83, *P* < 0.05), binds per primary fold (*r* = 0.86, *P* < 0.05)

<table>
<thead>
<tr>
<th>Rice genotypes</th>
<th>Leaf selection time (min)</th>
<th>Primary fold length(cm)</th>
<th>Binds/primary fold</th>
<th>Binds/fold</th>
<th>Fold length per 24 h (cm)</th>
<th>No. per primary fold</th>
<th>No. per bind</th>
<th>Folding time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN 1</td>
<td>1.5 ± 0.3 e</td>
<td>6.1 ± 0.4 ab</td>
<td>7.6 ± 0.6 a</td>
<td>14.3 ± 1.1 a</td>
<td>11.0 ± 0.4 a</td>
<td>307.6 ± 193.9 fg</td>
<td>42.0 ± 6.2 f</td>
<td>9.0 ± 1.6 ef</td>
</tr>
<tr>
<td>IR 36</td>
<td>1.6 ± 0.3 e</td>
<td>6.3 ± 0.2 a</td>
<td>7.0 ± 0.7 ab</td>
<td>13.7 ± 1.1 bc</td>
<td>10.7 ± 0.3 a</td>
<td>286.0 ± 17.9 g</td>
<td>54.3 ± 7.1 ef</td>
<td>8.4 ± 1.6 f</td>
</tr>
<tr>
<td>ASD 16</td>
<td>3.4 ± 0.1 bc</td>
<td>4.6 ± 0.1 d</td>
<td>5.4 ± 0.2 bc</td>
<td>8.7 ± 0.3 df</td>
<td>8.5 ± 0.2 b</td>
<td>393.3 ± 15.6 e</td>
<td>102.3 ± 5.2 c</td>
<td>17.4 ± 1.0 b</td>
</tr>
<tr>
<td>TKM 6</td>
<td>4.3 ± 2.6 ab</td>
<td>3.1 ± 0.2 f</td>
<td>2.8 ± 0.1 ef</td>
<td>6.7 ± 0.2 fg</td>
<td>4.7 ± 0.3 cd</td>
<td>838.0 ± 23.4 a</td>
<td>131.0 ± 5.6 a</td>
<td>21.1 ± 4.1 a</td>
</tr>
<tr>
<td>Ptb 33</td>
<td>4.6 ± 2.6 a</td>
<td>2.6 ± 0.1 g</td>
<td>3.2 ± 0.2 de</td>
<td>6.0 ± 0.4 g</td>
<td>5.0 ± 0.3 c</td>
<td>783.3 ± 23.8 ab</td>
<td>129.0 ± 6.2 a</td>
<td>19.6 ± 3.8 ab</td>
</tr>
<tr>
<td>TNAU LFR 831311</td>
<td>3.3 ± 2.3 abc</td>
<td>2.9 ± 0.1 fg</td>
<td>4.1 ± 0.2 cd</td>
<td>9.3 ± 0.3 cde</td>
<td>6.9 ± 0.2 bc</td>
<td>715.3 ± 25.9 bc</td>
<td>110.0 ± 4.1 bc</td>
<td>21.7 ± 3.9 a</td>
</tr>
<tr>
<td>Pusa Basmati</td>
<td>1.4 ± 0.1 e</td>
<td>5.5 ± 0.2 abc</td>
<td>5.8 ± 0.2 ab</td>
<td>9.0 ± 0.3 def</td>
<td>8.3 ± 0.2 b</td>
<td>382.3 ± 22.7 ef</td>
<td>64.3 ± 3.5 de</td>
<td>11.1 ± 1.9 cde</td>
</tr>
<tr>
<td>CB 200290</td>
<td>2.0 ± 0.3 de</td>
<td>5.6 ± 0.2 abc</td>
<td>6.0 ± 0.4 ab</td>
<td>7.7 ± 0.5 ef</td>
<td>8.2 ± 0.2 b</td>
<td>311.3 ± 19.3 fg</td>
<td>70.0 ± 5.5 d</td>
<td>11.1 ± 1.5 cd</td>
</tr>
<tr>
<td>CORH 1</td>
<td>2.6 ± 0.4 cd</td>
<td>5.4 ± 0.4 bc</td>
<td>5.6 ± 0.2 bc</td>
<td>10.7 ± 0.3 bcd</td>
<td>9.7 ± 0.3 ab</td>
<td>458.3 ± 21.6 e</td>
<td>70.0 ± 4.4 d</td>
<td>12.9 ± 1.1 bc</td>
</tr>
<tr>
<td>ADT 36</td>
<td>2.5 ± 0.6 cd</td>
<td>4.9 ± 0.2 cd</td>
<td>6.2 ± 0.3 ab</td>
<td>11.0 ± 0.4 bc</td>
<td>9.4 ± 0.2 ab</td>
<td>456.0 ± 20.4 e</td>
<td>75.3 ± 4.4 d</td>
<td>10.5 ± 2.6 de</td>
</tr>
<tr>
<td><em>O. minuta</em></td>
<td>3.0 ± 2.3 c</td>
<td>3.8 ± 0.1 e</td>
<td>2.5 ± 0.2 ef</td>
<td>12.0 ± 0.2 abc</td>
<td>6.8 ± 0.6 bc</td>
<td>593.3 ± 23.9 d</td>
<td>106.6 ± 9.4 c</td>
<td>21.0 ± 2.4 a</td>
</tr>
<tr>
<td><em>O. rhizomatis</em></td>
<td>3.0 ± 2.1 c</td>
<td>3.4 ± 0.1 ef</td>
<td>1.9 ± 0.5 f</td>
<td>7.3 ± 0.5 ef</td>
<td>5.4 ± 0.5 e</td>
<td>675.0 ± 25.1 cd</td>
<td>131.0 ± 7.9 a</td>
<td>17.2 ± 2.9 h</td>
</tr>
</tbody>
</table>

Values were arc square root transformed and the original values are given as mean ± SE. Values followed by the same letter in a column are not significantly different at *P* > 0.05 by Duncan’s test.
and binds per fold ($r = 0.71$, $P < 0.05$) showed significant positive correlations with leaffolder damage (Fig. 1). However, significant negative correlations were found between spinning characters, such as head swings per primary fold ($r = -0.81$, $P < 0.05$) and leaf folding time per primary fold ($r = -0.88$, $P < 0.05$), and leaffolder damage.

**Scatter plot between folding and spinning characters and leaffolder damage**

Scatter plot diagram was sketched between two major components of rice genotypes such as larval folding and spinning characters, and leaffolder damage and the genotypes were separated into four groups viz., resistant, moderately resistant, moderately susceptible and susceptible (Fig. 2). Group one included three resistant genotypes (Ptb 33, TKM 6 and TNAU LFR 831311) and two wild genotypes (O. rhizomatis and O. minuta). Group two comprised by one cultivated genotype (ASD 16) and one hybrid genotype (CORH 1). Group three included three genotypes, including two scented genotypes (Pusa Basmati and CB 200290) and one popular genotype (ADT 36). And the fourth group included two genotypes (TN 1 and IR 36). The same trend was also observed for the relationship of spinning characters and leaffolder damage. However, the genotype ASD 16 occasionally performed as resistant to leaffolder in both studies.

**Antixenosis in leaffolder resistance**

The time taken for initiation of spinning and length of leaf rolled by *C. medinalis* differed significantly among the selected genotypes. The time taken for initiation of spinning by second instar was found to vary from $(18.3 \pm 1.2)$ s to $(68.0 \pm 6.7)$ s after inoculation on genotypes (Table 3). Larvae took shorter duration for spinning on susceptible TN 1 and scented Pusa Basmati than on resistant TKM 6. A significant difference was observed in the length of leaf rolled per hour by second instar which ranged from $(1.4 \pm 0.3)$ cm/h to $(4.3 \pm 0.1)$ cm/h. The resistant genotypes TNAU LFR 831311 and TKM 6 recorded shorter fold length than the susceptible TN 1 and IR 36.

**Morphological characters for leaffolder resistance**

The diverse groups of rice genotypes differed in plant height, number of productive tillers per hill, number of green leaves per hill, leaf length and width, and leaf trichome density and length (Table 4). Similarly, the genotypes were also differed in leaffolder damage. Genotypes Ptb 33 and TKM 6 with narrower and longer leaves had the lowest level of leaffolder damage (11.76% and 12.26%) while IR 36 and TN 1 with wider and shorter leaves had the highest level of leaf folder damage (43.82% and 46.28%). There was no correlation between total number of green leaves per hill and leaffolder damage ($r = 0.09$, ns) (Fig. 3).
The incidence of folded leaves was positively correlated with leaf width ($r = 0.30$, ns) and total productive tillers ($r = 0.17$, ns) whereas significant negative correlation was observed with plant height ($r = -0.65$, $P < 0.05$), leaf length ($r = -0.53$, $P < 0.05$) and trichome length ($r = -0.43$, ns).

**DISCUSSION**

Behavioral studies form an integral part of the biology of insects and one of the major aspects involved in the concept of integrated control of insects. A thorough understanding of the behavioral repertoire of an insect pest species is a key element in the establishment of a successful program for the development of plant cultivars resistant to insect attack. In the present investigation, *C. medinalis* larvae invariably selected the middle part of the leaf for folding in all the rice genotypes and the folding parameters *viz.*, primary fold, whole leaf fold, binds per primary fold and fold were positively correlated to leaffolder damage (Fig. 2). Punithavalli et al (2011) observed that the *C. medinalis* leaf folds predominantly occurred in proximal midquarter and distal midquarter of the leaf and least in distal and proximal quarter of the leaf. However, the larvae were found to examine up to three or four leaves before final selection and took longer time to construct folds on resistant and wild genotypes *viz.*, TKM 6, TNAU LFR 831311, Ptbd 33, *O. minuta* and *O. rhizomatis*. Larval leaf selection was delayed in wild genotypes mainly due to the narrow and rough surface with presence of tough mid-ribs on

Fig. 2. Scatter plot between leaffolder damage and folding and spinning behaviors in each genotype.
Table 3. Length of leaf rolled and time taken for initiation of spinning of *C. medinalis* on selected genotypes.

<table>
<thead>
<tr>
<th>Rice genotypes</th>
<th>Second instar larva</th>
<th>Third instar larva</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initiation of spinning (s)</td>
<td>Length of leaf rolled (cm/h)</td>
</tr>
<tr>
<td>TN 1</td>
<td>18.3 ± 1.2 d</td>
<td>4.1 ± 0.1 a</td>
</tr>
<tr>
<td>IR 36</td>
<td>18.7 ± 1.2 d</td>
<td>4.3 ± 0.1 a</td>
</tr>
<tr>
<td>ASD 16</td>
<td>27.3 ± 4.6 c</td>
<td>2.1 ± 0.1 cd</td>
</tr>
<tr>
<td>TKM 6</td>
<td>68.0 ± 6.7 a</td>
<td>1.6 ± 0.1 de</td>
</tr>
<tr>
<td>PtB 33</td>
<td>57.0 ± 7.0 ab</td>
<td>1.6 ± 0.2 de</td>
</tr>
<tr>
<td>TNAU LFR 831311</td>
<td>45.0 ± 3.0 b</td>
<td>1.4 ± 0.3 e</td>
</tr>
<tr>
<td>Pusa Basmati</td>
<td>22.7 ± 2.2 cd</td>
<td>3.2 ± 0.2 b</td>
</tr>
<tr>
<td>CB 200290</td>
<td>31.0 ± 1.5 c</td>
<td>3.1 ± 0.4 b</td>
</tr>
<tr>
<td>CORH 1</td>
<td>24.3 ± 1.5 cd</td>
<td>3.1 ± 0.6 b</td>
</tr>
<tr>
<td>ADT 36</td>
<td>26.0 ± 4.0 cd</td>
<td>2.9 ± 0.2 bc</td>
</tr>
<tr>
<td><em>O. minuta</em></td>
<td>44.7 ± 3.8 b</td>
<td>3.4 ± 0.2 ab</td>
</tr>
<tr>
<td><em>O. rhizomatis</em></td>
<td>56.0 ± 2.9 a</td>
<td>1.9 ± 0.1 de</td>
</tr>
</tbody>
</table>

Values were arc square root transformed and the original values are given as mean ± SE. Values followed by the same letter in a column are not significantly different at $P > 0.05$ by Duncan’s test.

Table 4. Morphological characters of selected rice genotypes and their leaf damage.

<table>
<thead>
<tr>
<th>Rice genotypes</th>
<th>Productive tillers(No./hill)</th>
<th>Plant height (cm)</th>
<th>Green leaf length (cm)</th>
<th>Leaf width (cm)</th>
<th>Trichome density (mm²)</th>
<th>Trichome length (μm)</th>
<th>Leaffolder damage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN 1</td>
<td>13.0 ± 0.6 abcd</td>
<td>74.0 ± 1.5 b</td>
<td>24.7 ± 1.2 cd</td>
<td>39.3 ± 0.9 b</td>
<td>1.1 ± 0.1 b</td>
<td>2.4 ± 0.1 b</td>
<td>305.6 ± 2.91</td>
</tr>
<tr>
<td>IR 36</td>
<td>13.7 ± 0.9 abc</td>
<td>78.7 ± 1.7 bc</td>
<td>28.7 ± 0.9 de</td>
<td>43.7 ± 1.2 cd</td>
<td>1.4 ± 0.0 d</td>
<td>1.0 ± 0.1 de</td>
<td>582.2 ± 1.7 g</td>
</tr>
<tr>
<td>ASD 16</td>
<td>14.0 ± 0.6 ab</td>
<td>65.0 ± 1.5 a</td>
<td>25.3 ± 0.9 d</td>
<td>35.7 ± 0.9 a</td>
<td>1.1 ± 0.1 b</td>
<td>0.8 ± 0.1 e</td>
<td>597.8 ± 1.6 f</td>
</tr>
<tr>
<td>LFR 831311</td>
<td>11.3 ± 0.9 cde</td>
<td>105.7 ± 4.4 e</td>
<td>18.7 ± 1.2 ab</td>
<td>52.0 ± 0.6 f</td>
<td>1.1 ± 0.1 b</td>
<td>1.0 ± 0.1 d</td>
<td>910.8 ± 2.4 a</td>
</tr>
<tr>
<td>TNAU LFR 831311</td>
<td>10.7 ± 0.9 ef</td>
<td>79.0 ± 2.3 bc</td>
<td>17.7 ± 1.2 ab</td>
<td>36.0 ± 1.0 a</td>
<td>1.1 ± 0.0 b</td>
<td>0.4 ± 0.1 f</td>
<td>531.1 ± 2.0 h</td>
</tr>
<tr>
<td>CB 200290</td>
<td>11.0 ± 1.5 de</td>
<td>82.7 ± 2.7 cd</td>
<td>15.3 ± 0.9 a</td>
<td>43.0 ± 0.6 cd</td>
<td>1.1 ± 0.0 bc</td>
<td>1.4 ± 0.0 c</td>
<td>378.9 ± 1.5 j</td>
</tr>
<tr>
<td>CORH 1</td>
<td>12.3 ± 0.3 bcde</td>
<td>86.7 ± 0.1 d</td>
<td>20.0 ± 1.5 b</td>
<td>45.7 ± 1.2 de</td>
<td>1.2 ± 0.0 bc</td>
<td>2.8 ± 0.1 b</td>
<td>764.2 ± 0.1 d</td>
</tr>
<tr>
<td>ADT 36</td>
<td>15.0 ± 0.6 a</td>
<td>78.7 ± 2.3 bc</td>
<td>24.7 ± 1.8 cd</td>
<td>42.0 ± 0.6 c</td>
<td>1.3 ± 0.0 ed</td>
<td>1.7 ± 0.1 c</td>
<td>815.3 ± 5.0 c</td>
</tr>
<tr>
<td><em>O. minuta</em></td>
<td>8.7 ± 0.9 f</td>
<td>151.7 ± 2.9 h</td>
<td>21.0 ± 1.2 bc</td>
<td>45.3 ± 0.9 de</td>
<td>1.4 ± 0.0 d</td>
<td>1.0 ± 0.1 d</td>
<td>496.9 ± 1.8 i</td>
</tr>
<tr>
<td><em>O. rhizomatis</em></td>
<td>12.7 ± 1.2 abde</td>
<td>138.7 ± 2.3 i</td>
<td>21.0 ± 1.5 bc</td>
<td>47.3 ± 0.9 e</td>
<td>1.3 ± 0.0 ed</td>
<td>0.9 ± 0.1 de</td>
<td>368.4 ± 1.7 k</td>
</tr>
</tbody>
</table>

Values were arc square root transformed and the original values are given as mean ± SE. Values followed by the same letter in a column are not significantly different at $P > 0.05$ by Duncan’s test.

the leaves (Suresh, 1992). There was an increase in mobility or restlessness of larvae which could be the probable cause to construct shorter primary fold/whole leaf fold with lower number of binds on these resistant and wild rice genotypes. The results obtained from the present study are in conformity with the findings of Islam and Karim (1997) who reported that the larvae probably selected leaves based on width, length, toughness and condition of the edges which is normal or twisted. Narrower and tougher leaves were often rejected (Majumder et al., 1984; Saxena and Khan, 1991). The fold-making process appeared to be exhaustive and difficult on resistant and wild rice genotypes which were proved by correlation studies (Fig. 2). The negative correlation of leaffolder damage with leaf spinning parameters of head swings and folding time per primary fold indicated that larvae might have expended energy during fold construction by producing silken threads and head swinging from one edge to another of the leaf to make binds and folds (Fraenkel et al., 1981).

Scatter plot analysis based on leaffolder damage and leaffolding and spinning characteristics placed the genotypes into four groups viz., resistant (Ptb 33, TKM 6, TNAU LFR 831311, *O. rhizomatis* and *O. minuta*), moderately resistant (ASD 16 and CORH 1), moderately susceptible (Pusa Basmati, CB 200290 and ADT 36) and susceptible (TN 1 and IR 36) (Fig. 2). The genotypes in the same group have the similar combination of characteristics and are distinct from genotypes in other groups. Utilization of genotypes in different groups in crossing program will also lead to development of lines with stable and durable resistance, as they are likely to have different mechanisms or genes for resistance to leaffolder.

Observations of folding and spinning behavior and the mechanism of fold construction by leaffolder on rice indicated that narrow leaves might possess resistance to *C. medinalis*. Results of the present studies indicated that the resistant and wild genotypes, TKM 6, Ptb 33, TNAU LFR 831311, *O. minuta* and *O. rhizomatis* possessed moderately narrow leaves with
longer leaf length and shorter leaf width and thus supported this hypothesis. Hanifa and Subramanian (1973) reported several morphological characters associated with leaffolder infestation. The second leaf width was positively correlated to *C. medinalis* infestation whereas plant height and the second leaf length were negatively correlated, which were confirmed by the positive correlation of leaf width and the total number of productive tillers with leaffolder damage (Dakshayani et al, 1993; Islam and Karim, 1997). The trichome density and length were significantly higher on TKM 6 and Ptb 33 which interrupted the larval movement while feeding on resistant cultures. These results are also in agreement with the findings of Ramachandran and Khan (1991) who reported that the trichome density on the abaxial surface was higher in TKM 6 than in susceptible varieties. Results also indicated that plant height, trichome density and length, and leaf length may contribute to resistance (Fig. 3). Genotype TKM 6 was resistant to *C. medinalis*. The mechanism of resistance appeared to be antixenosis, and it is difficult for larvae to make folds and feed inside due to unsuitable leaf morphology (Pathak and Khan, 1994). Abenes and Khan (1990) and Heong (1990) observed that wild rice genotypes and TKM 6 affected larval survival, growth index and pupal weight of *C. medinalis*. The mechanism of resistance may be a combination of antixenosis and antibiosis. Association of plant morphological characteristics in general was in the same direction (positive or negative) for damage by *C. medinalis*. Therefore, careful plan is needed while developing cultivars with resistance to leaffolder. The folding and spinning characteristics of leaffolder in relation to morphological features were well studied in different categories of rice genotypes. On the basis of the present findings, we have identified some of the resistant genotypes such as TKM 6, Ptb 33 and *O. rhizomatis* which can be used as donors to begin the long term process of breeding for leaffolder resistance in rice.

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**REFERENCES**


Plant Interactions. CRC, Boca Raton, Florida: 162–188.


