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GENETIC AND PLANT GROWTH REGULATOR MANIPULATION OF RICE (ORYZA SATIVA L.) MESOCOTYL AND COLEOPTILE LENGTHS

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ABSTRACT

Significant differences in mesocotyl lengths of semidwarf and non-semidwarf rice (Oryza sativa L.) cultivars were observed. However, the relationship between plant height and mesocotyl length was found to be due to linkage rather than pleiotropism. Seed treatments of gibberellic acid (GA) significantly increased mesocotyl and coleoptile lengths in the laboratory study. The GA seed treatments significantly increased stand density compared to the untreated control in the field study. However, no significant differences were observed for plant height at maturity or grain yields among the GA treatments or the untreated control.

INTRODUCTION

Semidwarf rice (Oryza sativa L.) cultivars are short in stature (80 to 120 cm in height at maturity), have short and more upright leaves, greater nitrogen (N) responsiveness without lodging, and higher grain yields relative to taller traditional rice cultivars (Turner et al., 1982). Semidwarf rice cultivars are becoming more popular with rice producers in the southern states of Arkansas, Louisiana, Texas, and Mississippi. Semidwarf rice cultivars were seeded on 790,365 hectares in these states in 1988 (Matlick, 1988). Stransel (1984) stated that there may be problems with seedling emergence of semidwarf rice cultivars and changes in management practices may be required to maximize economic productivity of the semidwarfs.

Rice seedling emergence is a function of mesocotyl and coleoptile elongation. The mesocotyl in the rice seedling is the internode between the coleoptile node and the point of union of the root and the culm. The coleoptile is the cylinder-like protective covering that encloses the young plumule (DeDatta, 1981). Turner et al., (1982) reported that poor stand establishment of semidwarf rice cultivars is largely attributable to short mesocotyl length, and further stated that the semidwarfs have shorter mesocotyls than traditional, non-semidwarf rice cultivars.

Mesocotyl and coleoptile lengths are genetically controlled but mesocotyl and coleoptile elongation are also influenced by seedling depth and environmental factors (Turner et al., 1982). Kordan (1974) concluded that coleoptile elongation was enhanced by low oxygen (O2) levels while Chang and Bardenas (1965) reported that light inhibits mesocotyl elongation. Takahashi (1978) found that removing carbon dioxide (CO2) from the developing seedling decreased both coleoptile and mesocotyl elongation.

Turner et al., (1982) examined mesocotyl and coleoptile elongation of six rice cultivars at five seedling depths. Variability among cultivars existed for the mesocotyl and coleoptile elongation especially at different seedling depths. In general, the sum of the mesocotyl and coleoptile length equaled the seedling depth. However, the semidwarf cultivars ‘Bellemont’ and ‘M101’ did not emerge at the 10 cm seedling depth. Reduced emergence of these and other semidwarf rice cultivars at seedling depths exceeding 2.5 cm had led some researchers to theorize that there was a possible pleiotropic relationship between mesocotyl and coleoptile elongation and plant height.

Sunderman (1964) reported positive correlations between plant height and coleoptile lengths of winter wheat in three of five tests and coleoptile length was positively correlated with seedling emergence in one of two tests. Takahashi (1946) also found a positive correlation between coleoptile and culm length in barley but found no relationship between coleoptile length and seedling emergence.

Stowe and Yamaki (1957) postulated that since maize dwarfs are caused by single gene defects, the dwarfsness may be interpreted as a block in a biosynthetic pathway that ultimately leads to the production of gibberellin-like compound. They suggested that by adding gibberellic acid (GA), these blocks may be overcome and the requirement for the growth substance satisfied. However, Allan et al. (1962) found that dwarf and semidwarf wheat cultivars were not induced to grow to normal height by injections of GA3.

Bird and Ergle (1961) found significant increases in seedling emergence and seedling height of cotton when cotton seed was treated with potassium gibberellate (75% GA). The positive influence of the GA3 was thought to be associated with the increased rate of hypocotyl elongation.

When our study was initiated, the association of semidwarf rice cultivars and inadequate stand establishment were known. Furthermore, the proposed theory was that the mesocotyl and coleoptile were pleiotropic with plant height. The objectives of the study were to: (a) evaluate the potential mesocotyl and coleoptile elongation of semidwarf and standard cultivars, (b) determine the relationship between mesocotyl and coleoptile elongation and plant height in parental rice germplasm, (c) evaluate enhanced germlasm developed by hybridization and selection to determine the relationship of mesocotyl and coleoptile elongation to plant height, and (d) evaluate GA, as seed treatments on rice for mesocotyl and coleoptile elongation, stand establishment, plant height, and grain yield.

MATERIALS AND METHODS

Laboratory and field experiments were conducted from 1982 through 1988 to determine the mesocotyl, coleoptile, and total (mesocotyl + coleoptile) lengths of rice cultivars to determine the association of these parameters to plant height. Studies were also initiated to examine the effects of GA3 at rates of 10, 50, and 100 mg al/kg seed on seedling morphology, stand establishment, plant height, and seedling yield. One kilogram of seed was treated with solutions of GA3. The seed lots were then dried to inhibit germination.

The rice germplasm utilized in the mesocotyl/coleoptile and plant height study were the very-short-season cultivars ‘M101’, ‘L201’, and ‘Labelle’, and the experimental line RU7703008 (NWRX/C9881/PI331581). The semidwarf germplasm was represented by M101 (an early maturing California cultivar) and RU7703008 (a sister line of USDA-Texas Agricultural Experiment Station midseason cultivar, Belle-
RESULTS AND DISCUSSION

Laboratory Experiment

I. Mesocotyl/Coleoptile Evaluation of Parental Germplasm

The mesocotyl and total lengths of the two semidwarf genotypes, M101 and RU7703008, differed significantly from those of the taller genotypes, L201 and Labelle (Table 1). These data are similar to results reported by Turner et al. (1982), who found that semidwarf cultivars have shorter mesocotyl and total lengths than taller rice cultivars. Furthermore, the coleoptile length of L201 was significantly longer than the coleoptiles of RU7703008 and Labelle, but not that of M101.

Table 1. Mesocotyl, coleoptile and total (mesocotyl + coleoptile) lengths of four rice cultivars (laboratory experiment).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Mesocotyl</th>
<th>Lengths in mm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>M101</td>
<td>2.1</td>
<td>16.9</td>
<td>19.0</td>
</tr>
<tr>
<td>RU7703008</td>
<td>1.6</td>
<td>13.4</td>
<td>15.0</td>
</tr>
<tr>
<td>L201</td>
<td>16.9</td>
<td>31.6</td>
<td>48.5</td>
</tr>
<tr>
<td>Labelle</td>
<td>15.9</td>
<td>20.7</td>
<td>36.7</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>2.9</td>
<td>7.6</td>
<td>6.2</td>
</tr>
</tbody>
</table>

The germplasm in this study exhibited genetic differences in mesocotyl and coleoptile length which could be advantageous in the subsequent development of semidwarf cultivars. Furthermore, the slantboard technique previously described would be useful in determining mesocotyl/coleoptile lengths in large segregating populations because the technique would permit the saving and transplanting of individual seedlings that possess the desired seedling vigor traits.

II. GA, Seed Treatments

The GA seed treatments significantly increased mesocotyl, coleoptile and total lengths of the three cultivars compared to the untreated control (Table 2). The mesocotyl lengths of Rextmont at the GA, 10 mg/kg rate were significantly less than mesocotyl lengths at the GA, 50 and 100 mg/kg rate. No significant differences were observed among the GA, rates for mesocotyl lengths of Lemont or Mercury. Additionally, no significant differences were observed among the GA, rates for coleoptile or total lengths of any cultivar.

Table 2. Influence of GA, seed treatments on rice mesocotyl, coleoptile and total (mesocotyl + coleoptile) length of three rice cultivars (laboratory experiment).

<table>
<thead>
<tr>
<th>Seed Treatment mg/ha</th>
<th>L201</th>
<th>RU7703008</th>
<th>Labelle</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Control</td>
<td>1.7</td>
<td>9.6</td>
<td>11.1</td>
<td>9.4</td>
</tr>
<tr>
<td>GA, 0</td>
<td>16.3</td>
<td>26.7</td>
<td>63.0</td>
<td>26.7</td>
</tr>
<tr>
<td>GA, 50</td>
<td>12.4</td>
<td>24.8</td>
<td>37.2</td>
<td>23.8</td>
</tr>
<tr>
<td>GA, 100</td>
<td>15.8</td>
<td>22.6</td>
<td>38.4</td>
<td>23.8</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>3.6</td>
<td>9.7</td>
<td>7.2</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Germlap Enhancement - Field Study

In 1988, field studies to examine the effects of GA, seed treatments on stand establishment, plant height, and grain yield were conducted in the Southeast Branch Experiment Station, Rohwer, AR. The semidwarf, Lemont, was seeded at 2.5 and 7.5 cm depths at a rate of 112 kg/ha in Desha silt loam (Vertic Haplaudolls). Plots were nine drill rows wide (15 cm spacing) and 4.6 m in length.

A split-plot experimental design was used with seeding depth as the main plot and GA, seed treatments as subplots. Each treatment combination was replicated four times. The data were analyzed by the Statistical Analysis System (SAS Institute, 1982).

The data from the studies were statistically analyzed using the General Linear Mean Model (GLM) procedures provided by the Statistical Analysis System (SAS Institute, 1982).
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The new germplasm and their parents were evaluated for plant height versus mesocotyl/cotyledon elongation in the field in 1986 and 1987. Two of the semidwarf lines, designated (RU7703008 X L201)-512 and (RU7703008 X L201)-513, from the crosses produced significantly longer mesocotyls than the semidwarf parent, RU7703008 (Table 4). There was no significant difference in plant height between the new germplasm and RU7703008, a sister selection of Bellmont. However, these three genotypes were significantly shorter than L201, the normal height parent. There was no significant difference in coleoptile length of L201 or the new germplasm; however these three genotype sources have significantly longer coleoptiles than RU7703008 (Table 4). Therefore, these data verify that plant height and mesocotyl/cotyledon elongation in rice are not due to pleiotropy but rather these two plant characteristics are controlled by separate but closely linked loci.

Table 4. Mean separation of plant height, mesocotyl, cotyledon and total (mesocotyl + cotyledon) length of parental and new semidwarf germplasm that has normal length mesocotyls and cotyledons (germplasm enhancement experiment).

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Plant Ht cm</th>
<th>Mesocotyl</th>
<th>Cotyledon</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L201</td>
<td>90.5 a</td>
<td>26.8 a</td>
<td>29.8 a</td>
<td>56.6 a</td>
</tr>
<tr>
<td>(7703008 X L201)-512</td>
<td>78.5 b</td>
<td>16.7 b</td>
<td>35.1 a</td>
<td>51.8 a</td>
</tr>
<tr>
<td>(7703008 X L201)-513</td>
<td>86.6 b</td>
<td>16.2 b</td>
<td>29.4 a</td>
<td>43.6 b</td>
</tr>
<tr>
<td>7703008</td>
<td>83.5 b</td>
<td>6.2 c</td>
<td>19.3 b</td>
<td>25.5 c</td>
</tr>
</tbody>
</table>

P = 0.05

GA Seed Treatment - Field Study
Analysis of variance indicated there was a significantly greater stand density at the 2.5 cm seeding depth compared to the 7.5 cm seeding depth (Table 5). However, there was no difference between the seeding depths for plant height at maturity or grain yield.

Table 5. Influence of seeding depth on stand density, plant height, and grain yield of Lemont rice averaged over GA seed treatments.

<table>
<thead>
<tr>
<th>Seeding Depth cm</th>
<th>Stand Density plants/m²</th>
<th>Plant Height cm</th>
<th>Grain Yield kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>221</td>
<td>92.9</td>
<td>8110</td>
</tr>
<tr>
<td>7.5</td>
<td>137</td>
<td>91.3</td>
<td>7955</td>
</tr>
</tbody>
</table>

LSD = 0.05 32 NS NS

The GA seed treatments significantly increased stand density compared to the untreated control (Table 6). However, there was no difference among the GA seed treatments for stand density. Furthermore, there was no difference for plant height at maturity or grain yield when the GA seed treatments were compared to the untreated control. Although there were significant increases in mesocotyl, coleoptile, and total lengths from the GA seed treatments as determined in the laboratory study, these seedling elongation effects were not observed at maturity.

Table 6. Influence of GA seed treatments on stand density, plant height and grain yield of Lemont rice averaged over seeding depths.

<table>
<thead>
<tr>
<th>Seed Treatment</th>
<th>Stand Density plants/m²</th>
<th>Plant Height cm</th>
<th>Grain Yield kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Control</td>
<td>127</td>
<td>92.3</td>
<td>7705</td>
</tr>
<tr>
<td>GA3 10</td>
<td>191</td>
<td>92.8</td>
<td>8200</td>
</tr>
<tr>
<td>GA3 40</td>
<td>191</td>
<td>91.3</td>
<td>7950</td>
</tr>
<tr>
<td>GA3 100</td>
<td>201</td>
<td>92.1</td>
<td>8265</td>
</tr>
</tbody>
</table>

LSD 0.05 53 NS NS

CONCLUSIONS
These results indicate that there are differences in mesocotyl/cotyledon lengths of semidwarf and taller rice cultivars, but no pleiotropic relationship between plant height and mesocotyl elongation was found. Furthermore, two sources of germplasm ([RU7703008 X L201]-512, [RU7703008 X L201]-513) have been identified that have semidwarf plant height and mesocotyl/cotyledon potential that is similar to taller cultivars which can be utilized in rice breeding programs.

Also, the use of the GA seed treatments can enhance mesocotyl, coleoptile, and total elongation in present semidwarf rice cultivars. Field studies with Lemont demonstrated that stand establishment can be increased with the use of GA seed treatments.

LITERATURE CITED


