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ABSTRACT

Three experiments were conducted to evaluate the relationship of mesocotyl and coleoptile elongation to seedling vigor and plant height in rice *(Oryza sativa)*. A laboratory experiment was conducted to evaluate the potential lengths of the mesocotyl and coleoptile of semidwarf and standard rice genotypes. Four genotypes exhibited inherent differences in their ability for mesocotyl and coleoptile elongation. The semidwarf genotypes ('M-101' and RU 7703008) showed reduced mesocotyls, coleoptiles, and total lengths (mesocotyl + coleoptile); whereas, the tall plant type ('L-201' and 'Labelle') had comparatively longer mesocotyls, coleoptiles, and total lengths. It is assumed that mesocotyl elongation is the most important of the three parameters evaluated in seedling vigor, but total length is the least variable. Significant differences were detected among seeding depths and genotypes in the greenhouse experiment for emergence percentage, emergence index, coleoptile, and mesocotyl lengths. The field experiment verified that the low seedling vigor was due to the shorter mesocotyls and coleoptiles of the semidwarf genotypes in this test and was primarily responsible for poor stand establishment.

INTRODUCTION

Dwarf genotypes of wheat (*Triticum aestivum* L. *em.* Thell.) that were developed in Mexico by N.E. Borloug in the 1970's have doubled wheat yields in many countries and contributed to the "Green Revolution". Similar advances have been made in rice (*Oryza sativa* L.) with the release of dwarf and semidwarf genotypes. Short-statured genotypes are desirable for their increased lodging resistance and high nitrogen responsiveness which usually increase grain yield (Hargrove *et al.*, 1980, Mikkelsen and Dedatta, 1980).

Plant population is a major yield component and is often directly dependent upon seedling vigor and stand establishment. However, difficulties in establishing a stand of short-statured rice have been associated primarily with the germplasm that has been used in breeding programs to develop semidrawf genotypes (Dalrymple, 1980). Also, seedling emergence problems have been associated with the short-statured phenotype in winter wheat after deep seeding. The coleptile ruptures below the soil surface and does not allow the leaves to push through the soil (Sunderman, 1964). Research on semidwarf rice genotypes have indicated that reduced mesocotyl elongation seems to hinder seedling emergence and, consequently, leads to poor stand establishment (Turner *et al.*, 1982). Therefore, the mesocotyl and coleoptile have a major role in stand establishment of most monocotyledonous plants.

The mesocotyl is the internode between the coleoptile node and the point of union of the root and the culm. The mesocotyl (internode) only elongates in the dark; therefore, its length can be measured only when the seedlings have been grown in a dark environment (e.g., growth chamber or underground). The elongation of the mesocotyl elevates the coleoptile, which is the protective sheath enclosing the young leaves, above ground. Nagai (1958) used mesocotyl and coleoptile lengths to differentiate genotypes and indicated that the two traits could serve as indices of seedling vigor.

Knowledge of the relationship between the mesocotyl, coleoptile, and plant height is essential as breeders incorporate semidwarf genes into new and adapted rice genotypes. The objectives of the present study were to: a) determine the length of the mesocotyl and coleoptile of two semidwarf and two standard rice genotypes; b) compare the mesocotyl/coleoptile elongation phonomenon in laboratory, greenhouse, and field conditions; c) determine the effect of seedling depth of the genotypes on mesocotyl and coleoptile elongation; d) and examine the relationship between mesocotyl/coleoptile elongation, percentage emergence, and plant height.

MATERIALS AND METHODS

In this study three rice genotypes and one experimental line, all of diverse origin, were evaluated. The semidwarf genotypes were 'M-101' (an early maturing California genotype) and RU 7703008 (a sister line of a USDA-Texas Agricultural Experiment Station midseason genotype 'Bellemont'). The other two genotypes of comparatively taller stature were 'Labelle', a genotype developed by USDA and the Texas Agriculture Experiment Station, and 'L-201' (an early maturing genotype developed by the California Cooperative Rice Research Foundation). Three experiments were conducted at the Rice Research and Extension Center near Stuttgart, Arkansas.

LABORATORY, GREENHOUSE, AND FIELD EXPERIMENTS

A laboratory test was designed to determine the potential length of the mesocotyl and coleoptile of the four genotypes and to test the visibility of the seed. In this test, a modification of the slantboard technique described by Jones and Peterson (1976) was used. Moistened blotters (15 x 20 cm) were placed on acrylic plates of the same size and twenty seeds were placed on the blotters approximately one cm apart, germend down along a horizontal line 4.5 cm from the bottom edge of the blotter.

The seeds were held in position by a single thickness tissue that was moistened with distilled water. Plates, blotters, and adhering seed were placed in slotted racks that were made of acrylic plastic. Each rack held 15 plates. The entire assembly was placed in aluminum trays that contained enough distilled water to keep the lower edge of the blotters continuously wet. The trays were wrapped in black polyethylene bags to maintain high humidity, eliminate evaporative cooling, and to provide a dark environment because of the effect of light on mesocotyl/coleoptile elongation. The trays were placed in a temperature-controlled germinator for 10 days (at 25 °C ± 1.0), after which the mesocotyl and coleoptile lengths were measured. Abnormal or diseased seedling data were also recorded for percent germination, but their mesocotyl and coleoptile lengths were not measured because of abnormal growth and development of those seedlings.

The greenhouse test was designed to determine the effect of seeding depth and genotype on mesocotyl/coleoptile length and their subsequent influence on seedling emergence. A split-plot design with four replications was used. Seven seeding depths ranging from 1.3 to 8.9 cm (increments of 1.25 cm) were handled as main plots, and the four genotypes were sub-plots. Aluminum trays were lined with single thickness paper. Soil was added to the trays and uniformly spread to provide a thin layer on which the seeds could be planted. Each tray represented a particular

seeding depth. Four rows were marked in each tray and the genotypes were randomly assigned. Thirty seeds per row were planted and a marked garden label was placed vertically to attain the required seeding depth for each tray. Water was added at regular intervals to maintain adequate soil moisture for seed germination. Seedling emergence started on the fourth day after seeding and seedling counts were taken daily for eight days. The total number of seedlings for a particular day minus the previous total equaled the seedling emergence for an individual day. This information was used to determine the emergence percentage and emergence index (EI). The formula used to determine EI was the one used by Jones and Peterson (1976) and McKenzie *et al.*, (1980). The EI provides a weighted score for both early emergence and high emergence percentage.

A field experiment designed to complement the laboratory and greenhouse experiments was conducted. The four genotypes were seeded on a Cowboy silt loam soil, a fine montmorillonitic thermic Typic Albaqualf. The seeding depths were randomly assigned to the main plots and each main plot was replicated six times. The land was prepared and rolled so the soil was uniformly compact and essentially level. This allowed for uniform planting depth. Thirty mature seeds were planted in each row with a cone planter. To minimize variability of the main plots between replications due to planter effect, the planter plates were adjusted for each planting depth for each main plot. The seeding depths of 1.3, 2.5, 3.8, 5.1, 6.4 and 7.6 cm were tested.

Rows were 18 cm apart and 1.5 m long. Propanil was applied two weeks after seeding at the rate of 9.3 kg/ha for weed control. Urea fertilizer was applied at the rate of 133 kg N/ha in three split applications. The first fertilizer application was made three weeks after seeding and a 5 to 8 cm flood was applied and maintained until maturity. The number of emerged seedlings 20 days after seeding was recorded.

Statistical analysis of greenhouse and field data was accomplished by using SAS procedures of the General Linear Model and Analysis of Variance. Multivariate statistics were necessary because the model statements included more than one dependent variable (Helwig, 1979). Mean separations were by Duncan's Multiple Range Test (1955).

Table 1. Mean separation for coleoptile, mesocotyl and total length laboratory experiment.

Variety	Mesocotyl	Coleoptile
	- - - Lengths in mm - - -	
M-101	2.1	26.7
RU 7703008	1.6	13.4
L-201	16.9	31.6
Labelle	15.9	20.7
LSD 0.05	2.9	7.6

RESULTS AND DISCUSSION

The four genotypes differed significantly in mesocotyl, coleoptile and total length (Table 1). The mesocotyl and total lengths of M-101 and RU 7703008 were significantly shorter that those of L-201 and Labelle. This supported the assumption by Turner *et al.* (1982) that dwarf genotypes have shorter mesocotyl and total lengths as compared to standard genotypes. These data also showed that genotypes exhibit different potential for mesocotyl and coleoptile lengths and that differences in mesocotyl and coleoptile lengths can be selected by breeders in subsequent development of semidwarf genotypes for drill-seeded rice.

Emergence Percentage: A significant effect on seedling emergence was observed between seeding depths and genotypes (Table 2 and 3). The genotype differences could be attributed to their inherent mesocotyl and coleoptile length differences. Genotypes with the greatest total length (mesocotyl and coleoptile) in the laboratory test had correspondingly

Table 2. Percentage emergence of the four genotypes at seven different seeding depths greenhouse experiment.

Seeding depth	-Genotype-			
	M-101	7703008	L-201	Labelle
cm	Emergence (%)			
1.3	91.7	92.5	90.0	94.2
2.5	90.8	89.2	85.8	90.8
3.8	85.8	82.5	81.1	87.5
5.1	82.5	55.0	82.5	89.2
6.4	60.8	44.2	78.3	83.3
7.6	34.2	5.0	63.3	78.3
8.9	0.0	0.8	15.0	19.2
Cultivar Mean	63.7	52.7	71.0	77.5

LSD 0.05 for genotype differences = 3.6.

LSD 0.05 for seeding depth differences = 10.3.

Table 3. Emergence Index of four genotypes at seven different seeding depths greenhouse experiment.

Seeding depth	-Genotype-			
	M-101	7703008	L-201	Labelle
cm	Emergence (%)			
1.3	83.5	76.0	81.8	84.9
2.5	78.1	62.7	76.2	77.6
3.8	49.4	41.2	51.9	54.9
5.1	43.1	24.3	65.4	62.3
6.4	31.5	18.8	52.0	49.5
7.6	15.0	0.8	32.7	41.7
8.9	0.0	0.0	5.0	5.0
Cultivar Mean	42.9	32.0	52.1	53.7

LSD 0.05 for seeding depth differences = 20.3.

LSD 0.05 for genotype differences = 4.1.

higher emergence percentage at deep seeding in the greenhouse experiment. However, there was a consistent decrease in the emergence percentage as seeding depth increased.

Each genotype had a threshold seeding depth and many shallower depth gave an adequate stand establishment. Most seedling mortality occurred beore emergence, therefore, emergence percentage was one indicator of seedling vigor. This verified the assumption that the short-statured genotypes used in this test were less vigorous based on emergence and subsequent growth and development as compared to the standard genotypes, especially at deeper seeding.

Mesocotyl, Coleoptile, and Total Length. Significant differences among mesocotyl, coleoptile, and total length due to seeding depths and genotypes were detected (Table 4 to 6). The mesocotyl and coleoptile of L-201 and Labelle showed greater elongation potential than did M-101 and RU 7703008. These data agree with those of Mers' (1979) who found that in oats the reduction in mesocotyl growth was accompanied by a transient promotion of coleoptile growth that was apparently due to a reduction in auxin.

Table 4. Mesocotyl lengths of four genotypes at seven different seeding depths greenhouse experiment.

Seeding depth	Genotype			
	M-101	7703008	L-201	Labelle
cm	Mesocotyl/Length (mm)			
1.3	2.1	2.2	4.9	6.8
2.5	2.4	1.9	15.2	14.8
3.8	3.2	1.7	14.3	20.7
5.1	5.7	2.9	20.4	32.1
6.4	3.3	2.2	17.7	21.1
7.6	7.2	1.5	24.3	35.2
8.9	0.0	0.0	30.8	34.8
Cultivar Mean	3.4	1.8	18.2	23.6

LSD 0.05 for seeding depth differences = 8.4

LSD 0.05 for genotype differences = 2.1.

Table 5. Coleoptile lengths of four genotypes at seven different seeding depths greenhouse experiment.

Seeding depths	Genotype			
	M-101	7703008	L-201	Labelle
cm	Coleoptile/Length (mm)			
1.3	11.6	12.2	7.4	7.1
2.5	20.1	20.1	11.8	10.6
3.8	26.6	19.5	22.0	14.3
5.1	37.4	38.2	22.1	17.5
6.4	26.6	27.2	25.0	26.7
7.6	40.2	16.0	36.0	31.1
8.9	0.0	0.0	41.6	29.9
Cultivar Mean	23.2	19.0	23.1	19.6

LSD 0.05 for seeding depth differences = 12.5.

LSD 0.05 for genotype differences = 2.8.

Table 6. Arcsin emergence percent of the four genotypes planted at six seeding depths field experiment.

Seeding depth	Genotype				Seeding depth average
	M-101	7703008	L-201	Labelle	
cm	Arcsin %				
1.3	44.1	88.2	100.0	97.2	81.1 a
2.5	36.5	78.2	100.0	94.8	77.4 b
3.8	32.4	58.3	92.0	87.6	67.6 c
5.1	23.0	40.1	93.4	84.5	60.3 d
6.4	24.8	28.1	89.0	83.3	56.3 e
7.6	18.9	28.2	84.0	74.4	51.4 f
Cultivar average	30.0 d	53.5 c	93.1 a	87.0 b	

Means followed by same letter are not statistically different at the 0.05 level of probability.

Total length (mesocotyl + coleoptile) is an important factor in seedling vigor. Emergence occurs only when the coleoptile tip brings the primary leaf to the surface of the soil which is a combined effect of the mesocotyl and coleoptile. Data from this study and Turner *et al.* (1982) agree that total length is a more valuable parameter in seedling vigor studies than mesocotyl or coleoptile length alone. This assumption is based primarily on lower variability of the total length versus the variability of the mesocotyl or coleoptile lengths measured separately. For example, the coefficient of variability (CV) of the mesocotyl, coleoptile, and total length of both the laboratory and greenhouse tests were 38.2, 16.5 and 9.6 versus 32.8, 24.6, and 19.7%, respectively. The short-statured genotypes, M-101 and RU 7703008, showed a decrease in total length at deeper seedings, which indicates that emergence is impaired at deep seeding. Cultivars, L-201 and Labelle, which showed greater potential for mesocotyl elongation also exhibited higher emergence percentage. These data show that the mesocotyl, though highly variable, contributes more than the coleoptile to seedling vigor at deeper seeding depths.

This experiment was conducted to determine the relationship between the mesocotyl and coleoptile elongation in the laboratory and greenhouse experiments versus seedling emergence and plant height at maturity in field conditions. Analysis of variance detected significant differences among genotypes for seedling emergence and plant height. Significant differences are also detected among seeding depths for seedling emergence percent.

The genotypes M-101 and RU 7703008 showed poorer seedling emergence in the field experiment than in the greenhouse. This was probably due to soil compaction of the Crowley silt loam soil in the field after heavy rains (Table 6). A bar diagram showed significant differences between plant height and mesocotyl lengths by genotype (Fig. 1). Figure 1 shows that the short-statured genotypes M-101 and RU 7703008 exhibit reduced mesocotyl lengths and plant heights; whereas, L-201 and Labelle (tall plant types) had comparatively longer mesocotyls. This trend is a major concern among breeders because of the possibility of a pleiotropic effect of mesocotyl/coleoptile elongation and plant height. Furthermore, the assumption of many rice breeders that short-statured plants have a short mesocotyl and low total length which accounts for their low emergence percentage at deeper seeding is supported by these data. The opposite appears to be true for the tall phenotypes.

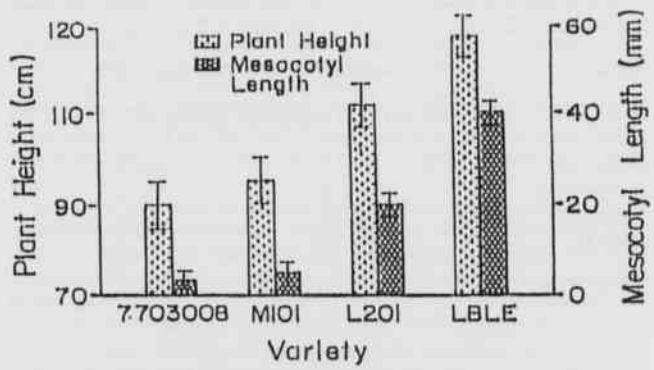

Figure 1. Plant height and mesocotyl lengths of four cultivars (data from 1981 and 1982).

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