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Mazo Price
University of Arkansas at Pine Bluff

R. H. Dilday
USDA-ARS

Arthur L. Allen
University of Arkansas at Pine Bluff

CHARACTERIZATION OF RICE (*ORYZA SATIVA* L.) ROOTS VERSUS ROOT PULLING RESISTANCE AS SELECTION INDICES FOR DRAUGHT TOLERANCE

MAZO PRICE
Dept. of Agriculture
UAPB
Pine Bluff, AR 71601

R.H. DILDAY
USDA-ARS
P.O. Box 287
Stuttgart, AR 72160

ARTHUR L. ALLEN
1890 Agric. Programs
UAPB
Pine Bluff, AR 71601

ABSTRACT

A technique described as Root Pulling Resistance (RPR) was used to evaluate genotypic differences in root growth and development of 50 rice germplasm accessions and cultivars. Several root characteristics in rice are associated with drought tolerance and avoidance capability of plants. The RPR measurements showed a significant positive correlation with maximum root length ($r = 0.69$), root thickness ($r = 0.75$), branching number ($r = 0.75$), and root dry weight ($r = 0.82$). Rice genotypes that had a high RPR value were identified as having longer, thicker, and denser root systems. The data indicated that high RPR measurements are strongly correlated with greater root penetration. Munji Sufaid Pak, IR 52 (IR5853-118-5) and Saunfia or Mabla Pak 329 had a significantly greater root length, root thickness, root number, root branching and dry weight as compared to IR 36. Also, there was no correlation between plant height and RPR. Furthermore, the data demonstrated that the RPR technique is ideal for selecting superior root systems and potential drought tolerant rice germplasm and cultivars.

INTRODUCTION

Arkansas leads the nation in rice production, producing 41.0 percent of the rice in the United States. In 1987, over one million acres of rice was grown in Arkansas, with an average yield of 116 bu/acre (Arkansas Agricultural Statistical Service, 1987). The net returns per acre for rice is higher than for other major field crops such as soybean, wheat, sorghum, and cotton; however, the cost of rice production is also higher. Irrigation expenses account for approximately 15 percent of the total rice production cost. Rice utilizes a greater amount of irrigation water than any other crop in Arkansas, and that water is taken from the declining ground waters of the Quaternary Aquifer (East Arkansas Water Conservation Project, 1985).

Rice is economically and nutritionally an important crop in the world. Over half of the world's rice is grown under rainfed conditions; therefore, drought often has a major impact on yield (O'Toole and Soemartono, 1981). There has been only a limited amount of research conducted on evaluating cultivars for drought resistance although the importance of rice is appreciated worldwide (Hargrove and Cabanilla, 1979). Several researchers (O'Toole and Moya, 1978; Hasegawa, 1963; Parao *et al.*, 1976, 1977; IRRI, 1978; Ekanayake *et al.*, 1986) have reported that drought tolerance in rice is correlated with low transpiration rate and that rooting patterns are important in determining the degree of tolerance of rice to water stress. Researchers (O'Toole and Soemartono, 1981; Ekanayake *et al.*, 1986) have demonstrated the effectiveness of a technique which involves the measurement of root pulling resistance (RPR) among rice cultivars. This method evaluates the relative rooting efficiency. Root pulling resistance is the vertical force required to pull a plant from the soil and this technique has been widely used to assess the nature of root development in cereal crops (Nass and Zuber, 1971; Arihara and Crosbie, 1982).

The objectives of this study were to: a) determine the RPR and root characteristics of 50 germplasm accessions and cultiars, b) compare RPR at different growth stages of plant development, c) determine correlations between RPR and several root characters and d) select genotypes that have the highest RPR for field evaluation to determine their drought tolerance.

MATERIALS AND METHODS

Fifty rice germplasm accessions and cultivars obtained from the USDA-ARS Rice Research and Extension Center at Stuttgart, AR were selected for this study. Two experiments were conducted at the University of Arkansas Pine Bluff Experimental Farm during the 1988 cropping season (June-October). The first experiment, seeded June 2, 1988, received the normal flood irrigation and 56 kg N/ha as urea at preflood or when the rice seedlings had 4-5 true leaves. Twenty-nine additional kg N/ha as urea was applied when the internodes of Newbonnet elongated to about 10 mm, and another 29 kg N/ha were applied 10 days later. Experiment II, seeded June 7, 1988, was only irrigated prior to July 1 to assure seedling emergence, and was not irrigated after July 1, 1988; and the second experiment was fertilized only at preflood at the same rate as the irrigated experiment. The test was conducted on a Calloway silt loam. The 50 entries in each experiment were planted in a randomized complete block design with four replicates. The entries were seeded in 20 hills about 0.5 m apart in two rows. Plot size was 0.5 m X 4.0 m. The seedlings were thinned to one plant per hill at about the third true leaf stage.

The RPR was measured 30 and 60 days after 90 percent emergence. The seedlings had approximately 4-6 true leaves 30 days after emergence, and the plants were beginning the reproductive stage at 60 days after emergence. A clamp apparatus attached to a spring balance was used to pull the plants from the soil. This technique has been described in detail by O'Toole and Soemartono, 1981; and Ekanayake *et al.*, 1986.

A subsample of four plants in each replication was subsequently washed and taken to the laboratory where root characteristics were recorded. Maximum root length (cm) was measured as the longest root attached to the pulled plant. Only roots thicker than 1 mm were recorded as thick roots. A scale of 1 to 5 was used to rate root branching. One accession that produced almost no root branching (Pak-34) and another accession that had excessive root branching (Munji Sufaid Pak) were used to develop visual ratings of 1 and 5, respectively. These accessions were then used as standards to determine the root branching scores for the other accessions: 1 = almost no branching, 2 = root branching greater than 1 but less than the mean of 1 and 5, 3 = moderate branching or a mean visual branching between the root branching of Munji Sufaid Pak and Pak-34, 4 = root branching greater than three but less than five and 5 = excessive branching. Root dry weight in grams was recorded for each entry.

Analysis of variance and mean comparisons by LSD was conducted for the RPR measurements and root characteristics. Correlations among the traits were calculated using simple correlation analysis.

RESULTS AND DISCUSSION

Plant height and days to 50% heading of five accessions with high, intermediate and low RPR are described in Table 1. Three of the accessions originated in Pakistan (Munji Sufaid Pak, Saunfia or Mabla Pak 329, and Basmati Sufaid Pak 187) and two accessions originated in the Philippines (IR 36 and IR 52 [IR5853-118-5]). The IBPGR-IRRI

Rice Advisory Committee report on "Descriptors for Rice *Oryza sativa* L." (IBPGR-IRRI Committee, 1980) defines different plant characteristics in rice. The following descriptors (plant, type, pancile type, grain type, hull cover, hull color, sterile lemma color, seed coat color, awning, lodging and straw strength) are defined in the IBPG-IRRI report. IR 36 had a spreading plant type; whereas, the other four accessions had an open plant type. All of the accessions had an intermediate panicle type, long grain, the hull cover had short hairs throughout, hull and sterile lemma color were straw yellow and the seed coat color was light brown. Staunfia or Mabla Pak 329 was partly awned and the awns are long; whereas, the other four accessions are partly awned but the anws are short. IR 36 was rated as having intermediate lodging resistance; whereas, Basmati Sufaid Pak 187 was rated as very weak and the other three accessions were rated as moderately strong.

Table 1. Plant height and days from emergence to 50% heading (maturity) for five accessions with high, intermediate and low root pulling resistance.

Germplasm	Ht(cm)	Days to Heading
Munji Sufaid Pak	123.05 a*	142 b
IR 52 (IR 5853-118-5)	82.50 b	147 a
Saunfia or Mabla Pak 329	93.97 b	139 b
Basmati Sufaid Pak 187	135.73 a	128 c
IR 36	57.05 c	124 c

* Means within columns with the same letter are not significantly different at the 0.05 level.

Table 2. Mean comparisons among rice accessions for Root Pulling Resistance 30 and 60 days after emergence.

Accessions	30 Day RPR Value	60 Day RPR Value
	- - - - KG - - - -	
Munji Sufaid Pak	22.3 a*	45.0 a
IR 52 (IR 5853-118-5)	22.0 a	44.3 a
Saunfia or Mabla Pak 329	11.6 b	39.6 b
Basmati Sufaid Pak 187	9.6 c	32.2 c
IR 36	9.5 c	32.1 c

* Means within columns with the same letter are not significantly different at the 0.05 level.

ROOT PULLING RESISTANCE

The five accessions representing the high, intermediate and low RPR groups that were pulled at two dates are shown in Table 2. A greater force was required to pull the plants 60 days after emergence as compared to the force needed to pull the plants 30 days after emergence; however, the order of the RPR for the different germplasm accessions remained the same on both dates. For example, Munji Sufaid Pak required the greatest force to pull the plants at both 30 and 60 days after emergence; whereas, IR 36 required the least force to pull the plants at both 30 and 60 days (Table 2). Munji Sufaid Pak and IR 52 (IR 5883-118-5) were among the top 10 accessions that gave the highest RPR measurements at 30 days after emergence; whereas, Saunfia or Mabla Pak 329 was intermediate and Basmati Sufaid Pak 187 and IR 36 gave consistently low RPR measurements at 30 days after emergence. A similar trend was obtained for RPR measurements 60 days after emergence. In fact, the correlation coefficient between RPR at 30 days (RPR-1) versus RPR at 60 days (RPR-2) was 0.88 (Table 3). Because the plants were larger when the data were collected on the second sampling date (60 days after emergence) the measuring device was changed from a maximum load of 25-kg to a maximum load of 50-kg.

Table 3. Correlation coefficients between Root Pulling Resistance and plant characteristics.

Plant Characteristics	r
Maximum root length	0.69*
Root thickness	0.75*
Root branching	0.75*
Root number	0.61*
Root dry weight	0.82*
RPR-1 vs. RPR-2	0.88*

* Significant at the 0.05 probability levels, N=50

PULLED ROOT CHARACTERISTICS

The accessions having higher RPR measurements also had longer roots, thicker roots, greater root branching, greater root number and higher root weight as compared to those accessions having low RPR measurements (Table 4). For example, Munji Sufaid Pak which consistently gave high RPR measurements produced higher values for root characteristics than did Basmati Sufaid Pak 187 and IR 36 which gave low RPR measurements (Table 4). Table 2 shows that significant differences due to genotype were present for each RPR measurement regardless of the observation date. Therefore, these data suggest that root characteristics among the genotypes will differ regardless of sampling date but the relative order will remain the same from date to date.

Table 4. Mean comparison among five rice accessions for root characteristics.

Accessions	Root Length (cm)	Root Thickness (mm)	Branching (0-5)	Root Number	Dry Weight (grams)
Munji Sufaid Pak	26.63 a	49.12 a	4.56 a	232.62 a	2.16 a
IR 52 (IR 5853-118-5)	21.25 c	37.75 b	4.19 a	184.37 b	1.64 b
Saunfia or Mabla Pak 329	22.43 b	28.00 c	2.75 b	106.87 c	1.08 c
Basmati Sufaid Pak 187	15.30 d	16.12 e	2.19 c	60.75 d	0.44 d
IR 36	10.72 e	22.00 d	1.81 c	68.75 e	0.49 d

* Means within columns with the same letter are not significantly different at the 0.05 level

RELATION OF RPR TO ROOT CHARACTERISTICS

The RPR data were significantly correlated with the root characteristics. For example, the RPR measurements were significantly correlated with maximum root length (r = 0.69), root thickness (r = 0.75), root branching (r = 0.75), root number (r = 0.61) and root dry weight (r = 0.82) (Table 3). Some of the root characteristics were positively correlated with each other; however, additional data are needed before the effect of these mutual associations can be explained.

CONCLUSIONS

The data in Tables 2 and 4, and the correlations presented in Table 3 demonstrate that RPR is an effective evaluation method for identifying plants with root systems having longer and thicker roots. The RPR measurements showed a significant positive correlation with maximum root length (r = 0.69), root thickness (r = 0.75), root branching (r = 0.75) root number (r = 0.61) and root dry weight (r = 0.82). The data indicated that high RPR measurements are strongly correlated with greater root penetration. Furthermore, there was no correlation between plant height and RPR. There was a significant correlation (r = 0.88) between RPR at 30 days after emergence as compared to RPR at 60 days after emergence.

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