Root growth of upland rice genotypes as influenced by nitrogen fertilization

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Abstract

The Plant root system is an important organ which supplies water and nutrients to plants. Information is limited on influence of nitrogen fertilization on upland rice root growth. A greenhouse experiment was conducted to evaluate the influence of nitrogen fertilization on root growth of 20 upland rice genotypes. The N rates used were 0 mg/kg (low) and 300 mg/kg (high) of soil. Nitrogen X genotype interactions for root length and root dry weight were highly significant ($P < 0.01$), indicating that differences among genotypes were not consistent at two N rates. Overall, greater root length and root dry weight were obtained at an N fertilization rate of 300 mg/kg compared with the 0 mg N/kg soil. However, genotypes differ significantly in producing root length and root dry weight. Nitrogen fertilization produced fine roots and more root hairs compared with control treatment. Based on root dry weight efficiency index (RDWEI) for N use efficiency, 70% genotypes were classified as efficient, 15% were classified as moderately efficient and 15% were classified as inefficient. Root dry weight efficiency index trait can be incorporated in upland rice for improving water and nutrient efficiency in favor of higher yields.

Key Words

Oryza sativa L., Oxisol, root dry weight efficiency index, shoot-root ratio.

Introduction

Root system is an important organ of plants. It absorbs water and nutrients from soil and supply to plant tops for their metabolic activities. Roots also give plants a mechanical support and supply hormones which help plants in many physiological and biochemical processes associated with growth and development. A vigorous root system is responsible for development of healthy plants and consequently higher yields. Roots which are left in the soil after crop harvest, improve soil organic matter content, nitrogen cycle and microbial activities (Sainju *et al.* 2005). All these activities improve soil structure, soil water holding capacity, water infiltration rate in the soil and reduce soil bulk density and soil erosion which ultimately leads to higher soil productivity. Root growth is controlled genetically and also influenced by environmental factors. Environmental factors which influence plant root growth are soil temperature, soil moisture content, solar radiation and soil physical, chemical and biological properties (Fageria 2009). Most of the root biomass of annual crops is located in the 0-20 cm soil depth. This may be associated with large amount of organic matter, nutrient accumulation and water availability in the top soil layer compared to lower soil depths (Sainju *et al.* 2005). In most of the research articles data related to plant tops growth and development are presented. Research data related to growth and development of crop root systems are limited. The objective of this study was to evaluate influence of nitrogen fertilization on root growth of twenty upland rice genotypes.

Materials and methods

The experiment was conducted in the greenhouse of National Rice and Bean Research Center of EMBRAPA, Santo Antôio de Goias, Brazil. The soil used in the experiment was an Oxisol. The genotypes used were: BRA01506, BRA01596, BRA01600, BRA02535, BRA02601, BRA032033, BRA032039, BRA032048, BRA032051, BRA042094, BRA042156, BRA042160, BRA052015, BRA052023, BRA052033, BRA052034, BRA052045, BRA052053, BRS Primavera, BRS Sertaneja. The N levels used were low (0 mg/kg) and high (300 mg/kg) and supplied through urea. Half of the N was applied at sowing and remaining half as topdressing 45 days after sowing. Four plants were maintained in each pot after germination. Experiments were conducted in plastic pots with 9 kg of soil in each pot. At the time of sowing, each pot received 200 mg P as triple super phosphate, 200 mg K as potassium chloride and 10 mg Zn/kg of soil as zinc sulfate. Each pot also received 10 g dolomitic lime four weeks before sowing. The liming material was having 33% CaO, 14% MgO and 85% neutralizing power. The pots were subjected to wetting and drying cycles. Experimental design was a complete block with three replications. Pots were water everyday to maintain soil moisture at about field capacity during growth cycle. Shoot and grain were separated at harvest and material was dried in an oven at 70 ^{0}C to a constant weight. Top-root ratio was

calculated by using the following formula (Fageria 1992):

$$\text{Top-root ratio} = \frac{Tops\ dry\ weight\ (grain\ plus\ straw)}{Roots\ dry\ weight}$$

Root dry weight efficiency index (RDWEI) for N use efficiency of genotypes was calculated using the following formula as proposed by Fageria (2009):

$$\text{RDWEI} = \frac{\dfrac{Root\ dry\ weight\ at\ low\ N\ rate}{Average\ root\ dry\ weight\ of\ 20\ genotypes\ at\ low\ N\ rate}}{\dfrac{Root\ dry\ weight\ at\ high\ N\ rate}{Average\ root\ dry\ weight\ of\ 20\ genotypes\ at\ high\ N\ rate}}\ \text{X}$$

Genotypes having RDWEI values >1 were classified as efficient, genotypes having RDWEI values, between 0.5 and 1 were classified as moderately efficient and those with RDWEI values < 0.5 were classified as inefficient in N use. At the time of harvesting, roots from each pot were removed manually to determine maximum length and dry weight. Roots were washed in water including distilled water several times before drying to a constant weight. Data were analyzed by analysis of variance and means were compared by Tukeys test at the 5% probability level.

Results and discussion
Root length
Nitrogen X genotype interaction was significant for root length and root dry weight; therefore data are reported separately for two N rates (Table 1). Root length varied from 27 cm produced by genotype BRA01600 to 43 cm produced by genotype BRA032039, with an average value of 30.49 cm at the low N rate (0 mg N/kg). Similarly at high N rate (300 mg N/kg), root length ranged from 21 cm produced by genotype BRA01506 cm to 40.33 cm produced by genotype BRS Sertaneja, with an average value of 31.99 cm. Overall, root length was 5% higher at the higher N rate compared to lower N rate. However, 35% genotypes produced lower root length at the higher N rate compared to lower N rate. Fageria (1992) reported higher root length of rice at low N rate compared to high N rate in nutrient solution. Fageria (1992) also reported that at nutrient deficient levels, root length is higher compared to high nutrient levels because tendency of plants to tap nutrients from deeper soil layers.

Root dry weight
Root dry weight varied from 0.87 g/plant produced by genotype BRA01596 to 1.78 g/plant produced by genotype BRA052034, with an average value of 1.38 g/plant at the lower N rate (0 mg N/kg). At the higher N rate (300 mg N/kg), root dry weight ranged from 0.40 g/plant produced by genotype BRA01506 to 4.14 g/plant produced by genotype BRA052023 g/plant, with an average value of 2.72 g/plant. Overall, root dry weight was 97% higher at the higher N rate compared to lower N rate. Fageria and Baligar (2005), and Fageria (2009) reported that N fertilization improved root dry weight in crop plants, including upland rice. The positive effect of N o root dry matter has been previously documented (Fageria 2009).

Visual evaluation of root growth
Overall, root growth was reduced in the 0 mg N/kg treatment compared to 300 mg N/kg of soil. However, there were differences among genotypes in root growth visually observed as length as well as weight. For example, root growth of genotypes BRA052015 was having minimum difference in length as well as weight at two N rates. Under low N rate, roots were thicker and having less hairs compared to higher N rate. Roots were thinner and root hairs were also fine at the high N rate compared to lower N rate. The root diameter and hairs may be indicative of the nutrient absorption capacity of the root system (Fageria 2009). Thinner roots with fine fine hairs can absorb more nutrients and water compared to thicker roots with less fine hairs. These results concur with published results on the effects of N fertilization on root characteristics (Drew *et al.* 1993).

Classification of genotypes for N use efficiency
Based on RDWEI, most efficient genotypes in N use efficiency were BRA052045, BRA052023, BRA052033, BRA042160, BRA032039, BRA052015, BRA052034, BRA052053, BRA02601, BRA02535, BRS Primavera, BRA042094, BRS Sertaneja and BRA032048. The three genotypes moderately efficient in N use efficiency were BRA032051, BRA042156 and BRA032033. Remaining three genotypes which were

Table 1. Root length and root dry weight of 20 upland rice genotypes as influenced by nitrogen fertilization.

Genotype	Root length (cm)		Root dry weight (g/plant)	
	0 mg N/kg	300 mg N/kg	0 mg N/kg	300 mg N/kg
BRA01506	34.67ab	21.00cd	0.92a	0.40f
BRA01596	30.00b	15.67d	0.87a	0.45f
BRA01600	27.00ab	25.33bcd	1.14a	1.03ef
BRA02535	31.67ab	30.00abcd	1.33a	3.25abcd
BRA02601	28.00b	32.67abc	1.11a	3.73ab
BRA032033	30.00a	28.00abcd	1.12a	2.41cd
BRA032039	43.00a	34.67abc	1.24a	3.77ab
BRA032048	28.50b	32.00abc	1.05a	3.62abc
BRA032051	30.67ab	35.67ab	1.31a	2.82bcd
BRA042094	30.33b	38.00ab	1.78a	2.31de
BRA042156	29.33b	33.00abc	1.19a	2.84bcd
BRA042160	29.67b	32.50abc	1.51a	3.33abcd
BRA052015	31.00ab	35.00abc	1.67a	2.83bcd
BRA052023	29.67b	26.50abcd	1.48a	4.14a
BRA052033	30.33b	31.33abc	1.56a	3.38abcd
BRA052034	29.00b	37.67ab	1.78a	2.58bcd
BRA052045	28.67b	37.67ab	1.75a	3.66abc
BRA052053	29.00b	36.50ab	1.65a	2.72bcd
BRS Primavera	29.33b	36.33ab	1.68a	2.49bcd
BRS Sertaneja	30.00b	40.33a	1.45a	2.68bcd
Average	30.49	31.99	1.38	2.72
F-Test				
N rate (N)	NS		*	
Genotype (G)	**		**	
N X G	**		**	
CV(%)	14.25		15.86	

[**]Significant at the 5 and 1% probability levels, respectively. Means followed by the same letter in the same column are not significant at the 5% probability level by Tukey test.

inefficient were BRA01506, BRA01596 and BRA01600. Limited data are available in the literature for classification of upland rice genotypes on the basis of root growth and hence, can not be compared with the published work.

Conclusions

Knowledge of root growth is important to know the ability of a crop to tap soil nutrients and water necessary to sustain plant growth. A significant interaction between genotypes and N rates was found for root growth because some genotypes were highly response to the N application while others were not. Thus genotypes selection for N use efficiency is an important aspect for improving root growth and consequently yield of upland rice in Brazilian Oxisols. Nitrogen fertilization produced thinner roots with fine root hairs compared with without N fertilization treatment. The genotypes were classified in three groups based on root dry weight efficiency index. Among 20 genotypes evaluated, 70% fell into efficient group, 15% fell into moderately efficient group and 15% fell into inefficient group.

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