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Genetic Variability among Different Rice Cultivars for Phosphorus Uptake and Utilization

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Abstract: Ten rice (*Oryza sativa*) genotypes were evaluated for growth and utilization efficiency of phosphorus (P), in hydroponics using modified Yoshida solution containing three levels of phosphorus viz. P_1 (10 mg L^{-1}), P_2 (5 mg L^{-1}) and P_3 (2.5 mg L^{-1}). Substantial differences were observed among varieties for accumulation of shoot dry weight (SDW), root dry weight (RDW), root: shoot ratio (RSR) as well as for phosphorus utilization efficiency (PUE). Overall IR-8 and Basmati-370 out yielded all other genotypes in shoot dry weight. In Basmati-370 also produced the highest RDW, while KS-282 was least RDW producer. Maximum RSR was exhibited by C-49-1-80 followed by EF-76-1, DM-15-13-1 and Basmati-370. Maximum PUE was exhibited by Basmati-Pak followed by Kernel. P_3 level showed highest value of PUE. Genotypes Basmati-Pak, Basmati-370 and Kernel showed maximum PUE as compared to all other genotypes and could be regarded as P-efficient.

Key Words: variability, rice, phosphorus, uptake, utilization

Introduction

Soil problems, such as declining soil fertility, soil erosion, soil salinity alkalinity etc. are the major constraints in the way of sustainable agriculture. Alkaline-calcareous nature of Pakistan soils is responsible for low fertilizer–use efficiency especially P (Rashid, 1992). Soil fertility surveys indicate that about 90% of the calcareous soils of Pakistan are phosphorous deficient (Memon *et al*., 1992). In Pakistan rice is grown on an area of about 2.4×10^6 hectares with a total production of 4.7×10^6 tones (Anonymous, 1998). Genotypes within species widely differ in their ability to take up and utilize mineral elements (Clark and Duncan, 1991). These differences for P efficiency have been associated with the ability of plants to grow under limited or excess amounts of P and in some cases, to show susceptibility or tolerance to P deficiencies.

The present study was undertaken to evaluate the growth behavior of rice genotypes at different levels of P in the growth medium in order to differentiate P-efficient and P-inefficient genotypes of rice.

Materials and Methods

Seeds of ten rice genotypes (KS-282, SC-53, DM-25-26, IR-6, Basmati-Pak, Kernel, Basmati-370, EF-76-1, DM-15-13-1 and C-49-1-80) were collected from Rice Research Institute, Kala Shah Kaku. Seeds were grown in two iron trays containing washed gravel. Canal water was used for irrigation. Fifteen days old seedlings were transplanted in foam plugged holes (two seedlings per hole) of thermopal sheets floating on nutrient solution in polyethylene lined iron tubs. Each tub contained 200 L Yoshida solution (Yoshida *et al*., 1976). Three different phosphorus levels viz. P_1 (10 mg L^{-1}), P_2 (5 mg L^{-1}) and P_3 (2.5 mg L^{-1}) were developed by adding NaH_2PO_4. The pH of the solution was maintained at 5 ± 0.5 with HCl and NaOH solutions. Experiment was laid out in completely randomized factorial design with four repeats. Seedlings were harvested after 30 days of transplanting, washed with distilled water, separated into shoot and root and blot dried. The harvested plants were dried at 70°C till constant weight. The shoot samples were ground through 40-mesh sieve grinder. The samples were subjected to analysis for growth and physiological parameters. Phosphorus utilization efficiency was calculated as {(1/phosphorus concentration in shoot, mg g^{-1}) $\times$ SDW, g 2plant^{-1})} (Siddiqi and Glass, 1981). The data were subjected to statistical analysis using Mstat-C program (Russel and Eisensmith, 1983).

Results and Discussion

Shoot dry weight: Statistical analysis showed significant ($p<0.05$) differences of shoot dry weight (SDW) on the means of P levels; genotypes and P level $\times$ genotype interaction (Table 1). Overall SDW ranged from 1.74 to 3.64 g 2plant^{-1}, among genotypes. IR-8 (3.64) and Basmati-370 (3.46) exhibited maximum amount of SDW followed by Kernel (3.28), while EF-76-1 (1.74) exhibited minimum SDW. Shoot dry weight decreased significantly at deficient levels of P in the growth medium, being highest in P_1 (3.07) and lowest in P_2 (2.40). A possible reason for reduction of shoot dry weight at deficient levels might be the failure of plant roots to absorb adequate amount of P from the growth medium. At adequate level IR-8 showed highest SDW whereas lowest SDW was shown by EF-76-1. At P_2 level highest SDW was yielded by Basmati-Pak whereas lowest was shown by EF-76-1 and at P_3 level highest SDW was shown by Basmati-370 whereas lowest was shown by IR-8. Differences in the ranges of SDW of the varieties, when grown with same P supply, indicated wide variation among these varieties to exploit the same growth environment for production of biomass, which is in accordance to Ahmad *et al*. (1998). They noticed that the differences in the SDW among the genotypes were less conspicuous at the deficient levels as compared to the adequate level.

Table 1: Shoot dry weight (g 2 plant^{-1}) of ten rice genotypes at three levels of Phosphorus

Genotype	P level (mg L^{-1})			Mean
	10	5	2.5	
KS-282	3.35cd	2.44e-h	2.38e-h	2.72cd
SC-53	2.40e-h	2.62e-h	2.72d-f	2.58c-e
DM-25-26	2.37e-h	2.35e-h	2.31e-h	2.35de
IR-8	5.22a	3.14c-e	0.57d-g	3.64a
Bas- Pak	2.33e-h	3.92bc	2.61d-g	2.95bc
Kernel	3.42cd	3.32cd	3.12c-f	3.29ab
Bas-370	4.62ab	2.82d-f	2.93d-f	3.46a
EF-76-1	.2.25e-h	1.61hi	1.37i	1.75f
DM-15-13-1	2.30e-h	2.38e-h	1.76g-i	2.15ef
C-49-1-80	2.42e-h	2.34e-h	2.23f-h	2.33de
Mean	3.07A	2.70B	2.40C	

Values having same letter(s) are statistically non significant at $p<0.05$

Table 2: Root dry weight (g 2 plant^{-1})of ten rice genotypes at three levels of Phosphorus

Genotype	P level (mg L^{-1})			Mean
	10	5	2.5	
KS-282	0.20kl	0.31h-l	0.43d-i	0.31e
SC-53	0.27i-l	0.61a-d	0.64a-c	0.51bc
DM-25-26	0.26i-l	0.51b-g	0.61a-c	0.46bc
IR-8	0.56a-e	0.52b-g	0.53b-f	0.54ab
Bas- Pak	0.15i	0.62a-c	0.53b-f	0.43c
Kernel	0.24j-i	0.49c-g	0.73a	0.49bc
Bas-370	0.41e-j	0.71a	0.73a	0.62a
EF-76-1	0.28i-l	0.35g-k	0.36f-k	0.33de
DM-15-13-1	0.28i-l	0.49b-g	0.47c-h	0.41cd
C-49-1-80	0.34g-k	0.65ab	0.47b-h	0.49bc
Mean	0.30B	0.525A	0.551A	

Values having same letter(s) are statistically non significant at $p<0.05$

Table 3: Root:shoot ratio of ten rice genotypes at three Phosphours levels

Genotype	P level (mg L^{-1})			Mean
	10	5	2.5	
KS-282	0.06l	0.13h-k	0.18d-g	0.12c
SC-53	0.11i-l	0.24a-c	0.23a-c	0.19a
DM-25-26	0.11j-l	0.22a-d	0.26ab	0.20a
IR-8	0.11l	0.17e-h	0.21c-e	0.16b
Bas- Pak	0.06l	0.16f-i	0.20c-f	0.14bc
Kernel	0.07kl	0.15g-j	0.24a-c	0.15b
Bas-370	0.09j-l	0.25a-c	0.25a-c	0.20a
EF-76-1	0.10h-l	0.25a-c	0.27a	0.21a
DM-15-13-1	0.12g-l	0.20c-f	0.28a	0.20a
C-49-1-80	0.14g-j	0.27a	0.21b-e	0.21a
Mean	0.10C	0.20B	0.23A	

Values having same letter(s) are statistically non significant at $p<0.05$

Table 4: Phosphorus utilization efficiency of ten rice cultivars at three Phosphorus levels (g^2 mg^{-1})

Genotype	P level (mg L^{-1})			Mean
	10	5	2.5	
KS-282	0.30hi	1.50d-f	2.09b-e	1.30cd
SC-53	0.21i	1.12f-i	3.42a	1.58bc
DM-25-26	0.22i	1.01f-i	2.50bc	1.24cd
IR-8	0.44g-i	1.27e-g	2.08b-e	1.26cd
Bas- Pak	0.20i	2.67ab	3.50a	2.12a
Kernel	0.28i	2.09b-e	3.42a	1.93ab
Bas-370	0.41g-i	0.91f-i	3.43a	1.58bc
EF-76-1	0.18i	0.96f-i	1.38d-f	0.84d
DM-15-13-1	0.19i	1.20f-h	1.64c-f	1.01d
C-49-1-80	0.21i	0.92f-i	2.24b-d	1.12cd
Mean	0.26C	1.36B	2.51A	

Values having same letter(s) are statistically non significant at $p<0.05$

Root dry weight: Table 2 shows that the differences of RDW were statistically significant ($p<0.05$) for P levels, genotypes, as well as genotype × P level interaction. Average RDW of varieties increased significantly from P_1 (0.30) to P_2 (0.52) level, but non-significantly from P_2 to P_3 (0.55 g 2plant^{-1}) levels. This increasing trend in RDW when genotypes were exposed to the P deficiency stress is against Ahmad *et al*. (1998). They noticed that average RDW decreased when cotton genotypes were exposed to P deficient conditions. So the increase in RDW in this experiment is very encouraging and it shows adaptability of genotypes to P stress condition. At adequate level, maximum RDW was shown by IR-8 (0.56), while minimum was shown by Basmati-Pak (0.15). At P_2 level, Basmati-370 (0.71) exhibited maximum RDW while minimum RDW was shown by KS-282 (0.31). At P_3 level Kernel and Basmati-370 showed maximum RDW (0.73), while minimum was shown by EF-76-1 (0.36). It is clear that Kernel and Basmati-370 showed maximum adaptability to P stress conditions because they had shown significant increase in RDW at deficient P conditions.
Overall RDW ranged from 0.31 to 0.61 g 2plant^{-1} among genotypes. Highest RDW was observed by Basmati-370 while lowest was observed in KS-282.

Root: shoot ratio (RSR): Data presented in Table 3 shows that the differences for RSR were statistically significant ($p<0.05$) for P levels, genotype as well as genotype × P level interaction. In this experiment, RSR increased significantly in plants grown at deficient levels of P as compared to adequate level. Maximum RSR (0.23) was observed at P_3 level, while minimum (0.10) was observed at P_1 level. The increase in RSR of genotypes when exposed to P deficiency stress shows that the genotypes in this study adapted themselves to P stress conditions and they diverted growth from shoot to root. Genotypes C-49-1-80 (0.21), EF-76-1 (0.21), DM-15-13-1 (0.20), Basmati-370 (0.20), DM-25-26 (0.20) and SC-53 (0.19), showed significantly higher RSR as compared to other genotypes, while minimum RSR (0.12) was shown by KS-282. At adequate level C-49-1-80 exhibited highest RSR (0.14), while lowest was shown by KS-282 (0.06). At P_2 level of P in the growth medium, same varieties showed highest (0.27) and lowest (0.13) RSR, respectively. At P_3 level, maximum RSR was shown by DM-15-13-1 (0.28), followed by EF-76-1 (0.21), while minimum was shown by KS-282 (0.18). Differences in RSR at same levels of P in the growth medium indicate the differential ability of these genotypes to exploit P deficient conditions.

Phosphorus utilization efficiency (PUE): Phosphorus utilization efficiency is the biomass production per unit of tissue P concentration (Siddiqi and Glass, 1981). This parameter can be used to classify the genotypes as P-efficient and P-inefficient. Table 4 shows PUE (g^2 mg^{-1}) of rice genotypes at three levels of P in the growth medium. In this experiment differences in PUE due to P levels, genotypes and P level × genotype interaction were statistically significant ($p<0.05$). Phosphorus utilization efficiency increased with the deficiency of P in the growth medium. High PUE may explain adaptability of the varieties to P deficiency stress. Average PUE of genotypes increased significantly from P_1 (0.26) to P_2 level (1.36) and from P_2 to P_3 level (2.57). At adequate level (P_1) maximum PUE was shown by Basmati-370 (0.41 g^2 mg^{-1}) while minimum was shown by EF-76-1 (0.18 g^2 mg^{-1}) and DM-15-13-1 (0.19 g^2 mg^{-1}). At P_2 level, highest PUE was shown by Basmati-Pak (2.67 g^2 mg^{-1}) while lowest was shown by Basmati-370 (0.91 g^2 mg^{-1}), followed by C-49-1-80 (0.92 g^2 mg^{-1}) and EF-76-1 (0.96 g^2 mg^{-1}). Similarly at P_3 level, maximum PUE was shown by Basmati-Pak (3.50 g^2 mg^{-1}) followed by Basmati-370 (3.42 g^2 mg^{-1}), Kernel (3.42 g^2 mg^{-1}) and SC-53 (3.42 g^2 mg^{-1}), while minimum PUE was showed by EF-76-1 (1.38 g^2 mg^{-1}). Over all among genotypes Basmati-Pak (2.12 g^2 mg^{-1}) and Kernel (1.93 g^2 mg^{-1}) were proved most efficient in P utilization, while EF-76-1 (0.84 g^2 mg^{-1}) was least P efficient genotype. This implies that as the concentration of P decreased in the growth medium, more dry matter was produced by genotypes (Basmati-Pak and Kernel) for each unit of the nutrient absorbed. So these genotypes should be included in more comprehensive screening programs under field conditions.

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