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Genetic Variability among Different Rice Cultivars for Zinc Uptake and Utilization

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Abstract: Genetic variability among eight rice cultivars was determined by conducting a solution culture experiment using modified Yoshida solution. Three Zn levels were developed by the addition of no DTPA (Zn_1), 25 μ M DTPA (Zn_2) and 50 μ M DTPA (Zn_3) to 0.035 mg L^{-1} Zn. Substantial differences were observed among genotypes for accumulation of shoot dry weight (SDW), root dry weight (ROW), root: shoot ratio (RSR) as well as for zinc utilization efficiency (ZnUE). Overall Kernel genotype produced maximum SDW at all the three levels of Zn. In case of RDW genotypes Kernel, Kashmir and Basmati-370 produced maximum RDW, while DM-25 was least RDW producer. Highest RSR was exhibited by Kashmir followed by Kernel and Basmati-370. Genotypes Kernel, Basmati-370 and KS-282 showed maximum ZnUE compared to all other genotypes and could be regarded as Zn-efficient.

Key words: Rice, cultivar, zinc, uptake, utilization

Introduction

Most soils of Pakistan are alkaline and calcareous with low organic matter content (Khattak and Parveen, 1986). Such soils are usually conducive to nutrient deficiencies particularly of N (nitrogen), P (phosphorus), Zn (zinc), Fe (iron) and/or S (boron). On an average, 49 % of the soils from various regions of the Punjab were observed Zn deficient (NFDC, 1998). During the last few years, a number of high yielding varieties of rice have been evolved and introduced in the cropping systems. This necessitates a proper evaluation of Influence of genetic variability among the new rice varieties on response to plants nutrients. Such basic information could also be used by plant breeders in evolving varieties to suit a soil type. Differential response to Zn fertilization among the new rice genotypes has not been investigated so far. Therefore, the present investigation was undertaken to evaluate the influence of genotype on Zn response in rice.

Materials and Methods

Seeds of eight rice genotypes (NIAB-6, Kernel, Basmati-370, KS-282, IR-6, Basmati-385, Kashmir and DM-25) were obtained from Rice Research Institute, Kale Shah Kaku. Seeds were grown in iron trays lined with polyethylene sheet and containing washed gravels. Canal water was used for irrigation. Nursery was raised prior to transplanting. Fifteen days old seedlings were transplanted in foam-plugged holes in thermopal sheets floating on 200 L modified Yoshida solution (Yoshida *et al.*, 1976) in polyethylene lined iron tubs. The pH of solution was maintained at 5.5 ± 0.5 with HCl or NaOH solutions. Three Zn levels were developed viz. Zn_1 (0.035 g L^{-1} Zn + No DTPA), Zn_2 (0.035 g L^{-1} Zn + 25 μ M DTPA) and Zn_3 (0.035 g L^{-1} Zn + 50 μ M DTPA). Each genotype consisted of four repeats and each repeat consisted of two plants per hole in the respective tubs. The experiment was laid out in a completely randomized factorial design. Seedlings were harvested after 45 days of transplanting, washed with distilled water, separated into shoot and root and blot dried. The harvested plants were dried at 70°C for 48 hours. The shoot samples were ground through 40-mesh sieve grinder. The samples were subjected to analysis for growth and physiological parameters. Zinc utilization efficiency was determined as {(1 /nutrient concentration in shoot, mg g^{-1}) x SDW, g 2plant^{-1}} (Siddiqi and Glass, 1981). The data were subjected to statistical analysis using Mstat-C program (Russell and Eisensmith, 1983).

Results and Discussion

Shoot dry weight: Statistical analysis showed significant ($p<0.05$) differences for shoot dry weight (SDW) on the means of In levels, genotypes and Zn level × genotype interaction (Table 1). Zn_1 level produced significantly the highest SDW (7.52) as compared to Zn_2 (5.79) and Zn_3 (5.35 g 2 plant^{-1}) levels which is in accordance with Cayton *et al.* (1985). They also observed increase in dry matter yield by increasing In levels in the growth medium. It might be due to the fact that with increasing Zn in the growth medium, plants absorb more zinc and translocate it to shoot for dry matter production. Genotype Kernel showed highest mean shoot dry weight (9.31) followed by Basmati-370 (7.49) and KS-282 17.46), while DM-25 produced minimum (2.47) yield. Similar results were also observed by NFDC (1998) according to which

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

Genotype	Zn levels			Mean
	Zn_1	Zn_2	Zn_3	
NIAB-6	5.01h-j	5.36g-i	5.79e-j	5.39
Kernel	12.91s	8.22cd	6.79d-g	9.31
Basmati-370	9.22c	6.17e-h	7.08d-f	7.49
KS-282	8.92c	7.28de	6.22e-h	7.46
IR-6	4.55ij	5.68f-j	4.38j	4.87
Basmati-385	6.06e-i	5.99e-i	4.77h-1	5.61
Kashmir	10.73b	5.27g-j	5.52g-j	7.18
DM-26	2.79k	2.37k	2.26k	2.47
Means	7.52A	5.799	5.35	

Values having same letter(s) are statistically non significant at $p<0.05$.
Zn_1 = 0.035 g L^{-1} Zn + No DTPA
Zn_2 = 0.035 g L^{-1} Zn + 25 μ DTPA
Zn_3 = 0.035 g L^{-1} Zn + 50 μ DTPA

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

Genotype	Zn levels Zn_1	 Zn_2	 Zn_3	Mean
NIAB-6	0.300f-h	0.392e-h	0.408e-h	0.367d
Kernel	1.350a	1.123bc	0.942cd	1.138a
Basmati-370	0.763d	1.128bc	1.115bc	1.002b
KS-282	0.367e-h	0.568e	0.492ef	0.476cd
IR-6	0.405e-h	0.433e-g	0.4500-g	0.429cd
Basmati-385	0.400e-h	0.575e	0.530e	0.502c
Kashmir	1.253ab	1.047c	0.925cd	1.075ab
DM-25	0.208h	0.255gh	0.243gh	0.2350
Means	0.631	0.690	0.638	

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

Table 3: Root-shoot ratio of eight rice genotypes at three levels of Zn

Genotype	Zn levels Zn_1	 Zn_2	 Zn_3	 Mean
NIAB-6	0.131e	0.071fg	0.068fg	0.090d
Kernel	0.156b-d	0.064f9	0.065fg	0.095b-d
Basmati-370	0.159bc	0.072fg	0.068fg	0.099bc
KS-282	0.153b-d	0.067fg	0.056g	0.092cd
IR-6	0.143de	0.075f	0.072fg	0.096b-d
Basmati-385	0.165ab	0.075f	0.07fg	0.103ab
Kashmir	0.148cd	0.066fg	0.063f9	0.092cd
DM-25	0.174a	0.076f	0.075f	0.108a
Means	0.154A	0.071B	0.067B	

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

Table 4: Zinc utilization efficiency (g^2 mg^{-1}) of eight rice genotypes at three levels of Zn

Genotype	Zn levels Zn_1	 Zn_2	 Zn_3	Mean
N1AB-6	38.169	75.20c-e	85.06c	66.14d
Kernel	82.84cd	127.25a	104.77b	104.88a
Basmati-370	58.00f	87.03c	103.53b	82.85c
KS-282	58.19f	104.99b	111.48b	91.55b
IR-6	32.029	75.58c-e	60.36ef	56.99e
Basmati-385	37.16g	80.98cd	67.76d-f	61.97de
Kashmir	72.15c-f	80.38cd	88.30c	80.28c
DM-25	15.87h	30.44gh	30.19gh	25.50f
Means	49.28B	82.73A	81.43A	

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

application of Zn at 2.5-10 kg ha^{-1} increased the yield of rice genotypes by 10% in Basmati-370 and Basmati-385 and by 12% in genotype 1R-6. Genotypes showed much differences in the mean SDW at the same level of Zn application in the growth medium. At Zn_1 level maximum SDW was produced by Kernel (12.91) followed by Kashmir (10.73), while minimum was produced by DM-25 (2.79). Similarly at Zn_2 level maximum shoot dry weight was observed in Kernel (8.22) while minimum was observed in DM-25 (2.37). At Zn_3 level maximum SOW was shown by Basmati-370 (7.08) followed by Kernel (6.79) and minimum was shown by DM-25 (2.26). The differences in the means of genotypes at same levels of nutrient in the growth medium show the existence of differential genetic potentials, which can be exploited for the identification of Zn efficient genotypes.

Root dry weight: Data presented in Table 2 shows that differences for RDW were statistically significant ($p<0.05$) for genotypes and Zn level × genotype interaction. Differences due to Zn levels were non significant, which is contrary to Babiker (1986). He noted significant influence of Zn application on RDW production of different rice cultivars. On an average, Zn_2 level showed maximum RDW (0.690) as compared to Zn_1 (0.631) and Zn_3 (0.638 g 2 plant^{-1}) levels. The differences in RDW among genotypes were significant. Table 2 shows that Kernel (1.138) produced highest ROW as compared to all other genotypes, while DM-25 produced minimum RDW (0.235). Differences among genotypes at same levels were statistically significant, which indicate wide variation among these genotypes to exploit the same growth environment for production of biomass. DM-25 showed minimum ROW at all the three levels. At Zn_1 level maximum RDW was shown by Kernel (1.350) followed by Kashmir (1.253). At Zn_2 and Zn_3 levels, highest RDW was observed in Basmati-370. Genotype Kernel showed significant decrease in RDW from Zn_1 (1.350) to Zn_2 (1.123) level and non-significant decrease from Zn_2 to Zn_3 (0.942) level. This might indicate that at Zn stress, the roots of Kernel absorbed Zn from the growth medium and efficiently translocated it to the shoot for dry matter production. Same behavior was also observed in genotype Kashmir.

Root Shoot Ratio (RSR): Statistical analysis showed significant ($p<0.05$) differences of root: shoot ratio on the means of Zn levels, genotypes and Zn level × genotype interaction (Table 3). The RSR decreased significantly from Zn_i (0.154) to Zn_2 level (0.071) but non-significantly from Zn_2 to Zn_3 (0.067) level, which is according to Qadir *et al.* (1988). He also noticed increase in root: shoot ratio with increased Zn application in rice crop. Genotype DM-25 (0.108) showed maximum RSR compared to all other genotypes, while N1AB-6 (0.090) showed minimum value. At Zn_1 level the RSR ranged from 0.131 to 0.174. The lowest RSR was observed in NIAB-6 while DM-25 produced highest RSR. At Zn_2 the RSR ranged from 0.064 to 0.076. The lowest ratio was observed in Kernel while DM-25 showed highest ratio. At Zn_3 lowest RSR was observed in KS-282 while DM-25 produced highest RSR (0.075). Therefore, it indicates that DM-25 had produced highest RSR at all the levels. Some scientists have recommended higher RSR under nutrient deficient conditions as a suitable screening criterion against nutrient deficiency stress.

Zinc utilization efficiency (ZnUE): Statistical analysis showed significant differences of zinc utilization efficiency ($p<0.05$) on the means of Zn levels, genotypes and Zn level × genotype interaction (Table 4). The Zn utilization efficiencies increased significantly from Zn, (49.28) to Zn_2 (82.73) levels in the growth medium, while remained statistically unchanged from Zn_2 to Zn_3 (81.43 g^2 mg^{-1}) level. High ZnUE may explain adaptability of the genotypes to Zn deficiency stress, as nutrient utilization efficiency of efficient genotypes increase with decreasing nutrient concentration in the growth medium. Maximum ZnUE was shown by genotype Kernel (104.88) followed by KS-282 (91.55), while minimum ZnUE was shown by DM-25 (25.50). Therefore, Kernel was proved most efficient genotype for Zn utilization. DM-25 showed minimum values of ZnUE (15.87, 30.44 and 30.19) at all the three levels. At Zn_1 and Zn_2 maximum values of ZnUE were shown by Kernel 182.64 and 127.75), while at Zn_3 maximum values were exhibited by 1CS-282 (111.48) followed by Kernel (104.77) and Basmati-370 (103.53). Memon *et al*. (1989) also documented differences of Zn utilization efficiency in maize crop under differential Zn levels.

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