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Effect of Zn Application on Rice Growth under Saline Conditions

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ABSTRACT

A solution culture experiment was conducted to determine the effect of Zn on plant growth under saline conditions. Two rice genotypes KS-282 (Salt tolerant) and BG 402-4 (Salt-sensitive) were compared. Two salinity levels (0 and 70 mol m^{-3}) were developed with NaCl. Four Zn levels (1, 10, 100 and 1000 nM Zn) were used externally. Number of tillers, shoot length, root length, shoot dry weight, root fresh and dry weights were significantly higher in tolerant-rice KS-282 than BG 402-4.

Key Words: Salinity; Zn application; Rice

INTRODUCTION

Salinity is a major threat to the sustainability of irrigated agriculture in arid and semi-arid regions of the world. However paddy production from marginal salt-affected soils can be increased by cultivating salt-tolerant genotypes of rice and by adopting site-specific management practices including proper application of plant nutrients to reduce nutritional imbalance effects has significance (Aslam *et al.*, 1996)

Zinc deficiency is common in the rice tract of Pakistan and other South Asian countries (Katyal & Ratten, 1993). In Pakistan, 0.7 million hectares of rice soils are Zn deficient (Ponnamperuma, 1981). Saline soils are usually deficient in Zn (Ponnamperuma & Bandyopadhya, 1980).

Finkelestein (1987) stated that Zn rapidly decreased the permeability to Na^+ by decreasing the diameter of natural pores of the biomembrane of the plant to the extent that they become single file pore. It was therefore considered worthwhile to study the effect of Zn in improving rice growth under saline conditions.

MATERIALS AND METHODS

A pot experiment was conducted in the wire house, Department of Soil Science, University of Agriculture, Faisalabad. In hydroponic media, two rice cultivars (BG 402-4 and KS-282) were grown. Nursery was raised in gravel culture and canal water was applied for irrigating the nursery. Fourteen-day old seedlings were transplanted in holes of polystyrene sheets floating over 100 liters of nutrients-solution (Yoshida *et al.*, 1972) contained in the plastic tubs. Two plants per hole were transplanted. Experiment was laid out in complete randomized design with 3 repeats. Initially Zn free Yoshida nutrient-solution was applied and then Zn was externally added @ 1, 10, 100 or 1000 nM. Two salinity levels (0, 70 mol m^{-3} NaCl) were developed by adding NaCl @ 23.3 mol m^{-3} per 24 hours.

Rice was harvested three weeks after salt-stress. Immediately after harvest, root fresh and dry weights, shoot dry weight, number of tillers, shoot length and root length were recorded. The data thus collected was analyzed statistically following methods described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Plant Growth

Tillers. The data revealed that both the salinity and Zn supply under saline conditions significantly reduced the number of tillers $plant^{-1}$ in both the rices (Table 1). However, reduction in number of tillers $plant^{-1}$ was greater in KS-282 compared to BG 402-4. There was a gradual and significant improvement up to Z_3 (100 nM Zn) in the number of tillers $plant^{-1}$ of BG 402-4 after which there was no improvement, whereas significant improvement under 0 mol m^{-3} NaCl salinity (control) was only up to Z_2 (10 nM Zn) in BG 402-4 which was decreased at the highest external Zn concentration of 1000 nM Zn and was statistically at par with Z_1 (1 nM Zn).

Under saline conditions (70 mol m^{-3} NaCl), increasing external concentration of Zn did not result in an improvement of number of tillers $plant^{-1}$ in both the cultivars rather it tended to decrease with increasing external Zn concentrations. The data indicated that Zn requirements of KS-282 were higher than that of BG 402-4.

Table I. Effect of Zn application on tillering capacity (tillers plant^{-1}) in two rice genotypes grown under saline conditions

Zn concentration (nM)	NaCl salinity (mol m^{-3})				
	O (Control)		70		Mean
	KS-282	BG402-4	KS-282	BG402-4	
1 (Z_1)	8.23 cd	7.83 de	8.67 cd	6.00 ef	7.68 B
10 (Z_2)	11.34 b	10.00 bc	6.66 def	5.00 f	8.25 B
100 (Z_3)	14.34 a	10.00 bc	8.00 cde	4.67 f	9.25 A
1000 (Z_4)	14.0 a	8.66 cd	6.67 def	5.00 f	8.58 AB
Mean	11.975 A	9.125 B	7.500 C	5.167 D	

Means with same letter(s) are statistically similar according to the DMR Test (P=0.05)

Under non-saline conditions, however no response was observed to Zn application. These results are contrary to those of Mahmood *et al.* (1998) who claimed beneficial effect of Zn application to both saline and non-saline conditions. Being salt tolerant, rice KS-282 produced higher number of tillers plant^{-1} both under non-saline (control) and saline (70 mol m^{-3} NaCl) conditions.

Shoot Dry Weight. The data (Table II) show that both salinity and Zn significantly reduced the shoot dry weight in both the rice varieties. However, reduction was greater in BG 402-4 compared with that of KS-282.

Zinc application improved the shoot dry weight in both the cultivars under non-saline conditions. This improvement in shoot dry weight was although consistent but non-significant except at the highest external Zn concentrations (1000 nM Zn) for KS-282 whereas significant improvement was only up to Z_2 (10 nM Zn) in BG 402-4 and then it decreased significantly. The lowest shoot dry weight was found at Z_4 (1000 nM Zn) under saline-conditions (70 mol m^{-3} NaCl) increasing external concentrations of Zn did not result in the improvement of shoot dry weight in both the cultivars rather it tended to decrease with increasing external Zn concentrations and this decrease was significant at the highest external Zn supply in case of BG 402-4. Thus Zn supply at this stage did not help in improving dry matter yield of both the rices under saline conditions.

Comparison of genotypes depicted that KS-282 produced significantly higher shoot dry weight at all the Zn levels except (10 nM Zn) under saline (70 mol m^{-3}) and non saline (control) conditions than the other cultivar. Similar findings were reported by Aslam *et al.* (1994) who advocated that salt tolerant genotypes (KS-282, NIAB-6 and IR-9) gave higher growth at higher salinity level. Zinc x salinity x genotype interaction indicated that the lowest shoot dry weight was found in

Table II. Effect of Zn application on shoot dry weight (g plant-1) in two rice genotypes grown under saline conditions

Zn concentration (nM)	NaCl salinity (mol m^{-3})				
	O (Control)		70		Mean
	KS-282	BG402-4	KS-282	BG402-4	
1 (Z_1)	1.260 cd	1.057 e	0.647 gh	0.403 ij	0.842 A
10 (Z_2)	1.358 bc	1.460 ab	0.510 hi	0.393 ij	0.930 A
100 (Z_3)	1.457 ab	1.160 de	0.730 fg	0.313 j	0.915 A
1000 (Z_4)	1.577 a	0.847 f	0.423 ij	0.073 k	0.730 B
Mean	1.413 A	1.131 B	0.577 C	0.296 D	

Means with same letter(s) are statistically similar according to the DMR Test (P=0.05)

Table III. Effect of Zn application on shoot length (cm plant^{-1}) in two rice genotypes grown under saline conditions

Zn concentration (nM)	NaCl salinity (mol m^{-3})				
	O (Control)		70		Mean
	KS-282	BG402-4	KS-282	BG402-4	
1 (Z_1)	48.0 NS	46.67	42.67	41.33	46.67 A
10 (Z_2)	51.0	49.33	43.00	41.00	46.08 A
100 (Z_3)	50.5	46.50	44.67	37.33	44.75 A
1000 (Z_4)	54.0	43.67	48.33	29.33	43.83 A
Mean	50.87 A	46.54 B	44.66 C	37.25 D	

Means with same letter(s) are statistically similar according to the DMR Test (P=0.05)

Table IV. Effect of Zn application on root fresh weight (g plant-1) in two rice genotypes grown under saline conditions

Zn concentration (nM)	NaCl salinity (mol m^{-3})				
	O (Control)		70		Mean
	KS-282	BG402-4	KS-282	BG402-4	
1 (Z_1)	2.018 NS	1.577	1.020	0.607	1.305 A
10 (Z_2)	1.760	1.920	0.960	0.677	1.329 A
100 (Z_3)	1.593	2.093	1.063	0.743	1.373 A
1000 (Z_4)	2.233	1.347	0.915	0.393	1.222 A
Mean	1.901 A	1.734 B	0.990 C	0.605 D	

Means with same letter(s) are statistically similar according to the DMR Test (P=0.05)

BG 402-4 under saline conditions at the highest level of Zn (1000 nM Zn).

Shoot Length. The data (Table III) indicate that no significant effect of Zn supply was observed on shoot length both under saline and non-saline soil conditions.

Interactions of Zn with salinity and/or genotype were also non-significant. Shoot length of both cultivars was statistically similar at 0 and 70 mol m^{-3} NaCl salinity. These results are opposite to those reported by Saxena (1990) who observed that Zn caused an increase in shoot length when Zn was applied @ 5 ppm. Reduction in shoot length of rice might be due to excessive accumulation of salts in the cell wall which modified metabolic activity and hence limited the cell wall elasticity and its cell walls became rigid. As a consequence, the turgor pressure efficiency in the cell enlargement decreased. These processes may cause the shoot to remain small (Accves *et al.*, 1975; Aslam *et al.* 1993).

Root Fresh Weight. The data (Table IV) show that Zn application affected root fresh weight non-significantly. Two rice genotypes differed significantly under saline conditions. Salinity decreased root fresh weight in both the cultivars compared with the control. Since growth under saline conditions is an energy demanding process (Nieman, 1980), therefore reduction in growth is obvious. Root fresh weight of KS-282 (salt tolerant) was higher compared to that of BG 402-4 (salt sensitive) under saline conditions. Yeo and Flowers (1984) noticed similar findings. They advocated that the growth in sensitive varieties was suppressed due to excessive Cl^- ion toxicity and excessive entry of other toxic ions e.g. Na^+ in the plant root. The interactions between variety and salinity, salinity and Zn salinity, and Zn and variety, were found non-significant.

Table V. Effect of Zn application on root dry weight (g $plant^{-1}$) in two rice genotypes grown under saline conditions

Zn concentration (nM)	NaCl salinity (mol m^{-3})				
	O (Control)		70		Mean
	KS-282	BG402-4	KS-282	BG402-4	
1 (Z_1)	0.277 bc	0.230 c	0.127 de	0.073 ef	0.177 B
10 (Z_2)	0.287 bc	0.327 ab	0.127 de	0.080 ef	0.205 A
100 (Z_3)	0.277 bc	0.247 c	0.117 de	0.080 ef	0.180 AB
1000 (Z_4)	0.373 a	0.167 d	0.113 de	0.023 f	0.169 B
Mean	0.303 A	0.242 B	0.121 C	0.064 D	

Means with same letter(s) are statistically similar according to the DMR Test (P=0.05)

Root Dry Weight. Application of Zn significantly

Table VI. Effect of Zn application on root length (cm plant-1) in two rice genotypes grown under saline conditions

Zn concentration (nM)	NaCl salinity (mol m^{-3})				
	O (Control)		70		Mean
	KS-282	BG402-4	KS-282	BG402-4	
1 (Z_1)	13.0 NS	11.0	11.0	10.83	11.46
10 (Z_2)	11.67	12.0	11.0	11.30	11.49
100 (Z_3)	11.67	11.0	11.34	10.67	11.67
1000 (Z_4)	11.34	9.33	11.80	10.00	10.62
Mean	11.92 A	10.833 B	11.78 C	10.70 D	

Means with same letter(s) are statistically similar according to the DMR Test (P=0.05) affected the root dry weight of two rice genotypes (KS-282 and BG 402-4) grown under saline conditions (Table-5). Maximum root dry weight was observed in KS-282 when Zn was applied @ Z_4 (1000 nM Zn) and it was maximum in BG 402-4 when Zn was applied @ Z_2 (10 nM Zn) at 0 mol m^{-3} NaCl salinity. The other external concentration of Zn at this salinity level produced statistically similar root dry weight. Root dry weight was negatively affected because of increasing external salt concentration in both the cultivars. However, cultivars did show differences, and KS-282 had the highest root dry weight compared to BG 402-4 both under saline and non-saline conditions

Reduction in root dry weight of rice due to saline conditions may be attributed to salt induced shrinkage and even complete distortion of chloroplast (Strongonov, 1962). The reduction in root dry weight due to salinity may be attributed to the toxic affects of excess ions e.g. Na^+ and Cl^- under saline conditions (Bernstein, 1961).

Root length. The Zn application did not significantly affect the root length under saline and non saline conditions (Table VI). Maximum root length (11.68 cm) was observed under control. Further, root length was also not affected because of salt stress. The difference in root length of two rice genotypes is because of their genetic diversity. Earlier studies show that root length/growth is less affected due to salinity compared to shoot length/growth (Aslam *et al.*, 1993).

CONCLUSION

From this study, it is concluded that maximum growth was observed under non-saline conditions (control 0 mol m^{-3} NaCl) and minimum growth when 70 mol m^{-3} NaCl salinity was imposed. External application of Zn caused increase in plant growth and maximum was observed when Zn was applied @ 10 nM Zn in most of the cases. Zinc effect was most pronounced in case of salt tolerant rice genotype KS-282 as compared to BG 402-4 salt sensitive rice genotype.

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