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Growth Response of Rice (*Oryza sativa* L.) to Fertilizer Nitrogen in Salt-Affected Soils

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ABSTRACT

The yield and chemical composition of rice grown on artificially salinated/sodicated soil receiving different rates of fertilizer nitrogen were evaluated in pots filled with 10 kg soil. Soil was salinated to different salinity/sodicity levels using mixture of salts [S_o (EC_e 1.6 dS m^{-1} + SAR 3.22), S_1 (EC_e 5.6 dS m^{-1} + SAR 29.3), S_2 (EC_e 6.1 dS m^{-1} + SAR 44.3) and S_3 (EC_e 6.3 dS m^{-1} + SAR 55.46)]. Nitrogen rates were 100, 125 and 150 mg kg^{-1} soil as $(NH_4)_2SO_4$ while basal P and K were applied each at the rate of 45 mg kg^{-1} soil as SSP and K_2SO_4, respectively at the time of transplanting seedlings. Six healthy seedlings of rice per pot (30 days old) were transplanted which, after two weeks, were thinned to four per pot. The crop was harvested at maturity. Paddy was analysed for N, P and K contents. Soil samples after the harvest of crop were analysed for pH_s, EC_e and N, P, K, Na and Ca concentrations. Maximum plant height (112.33 cm) was obtained at S_0 while minimum (98.88 cm) at S_3. Maximum paddy yield was observed where N @ 150 mg kg^{-1} soil was applied. The control produced higher yield of 57.04 g per pot while increasing salinity/sodicity adversely affected the paddy yield. There were no considerable change in EC_e, pH_s and SAR of soil after the crop harvest. Overall, it was concluded that even at higher levels of salinity/sodicity, fertilizer N remained beneficial.

Key Words: Salinity; Sodicity; Paddy; Mineralization

INTRODUCTION

About one million hectares of the famous rice tract of Pakistan suffers from moderate to high soil salinity/sodicity, high pH and scarcity of good quality irrigation water. The unfavourable conditions as well as inadequate and imbalance use of plant nutrients in these and other similar soils cause a considerable decline in paddy yield (Niane, 1987). No doubt soil salinity alters the uptake of nutrients by plants but the use of fertilizers alleviates to some extent the detrimental effects of moderate salinity and help to improve the economic yield of crops. Therefore, in addition to other agronomic practices, successful crop production on moderately salt-affected soils demands judicious use of plant nutrients, particularly nitrogen. Rice crop is moderately salt tolerant and a number of workers have reported 50% yield reduction at EC of 7 dS m^{-1} (Yeo & Flowers, 1984; Maas & Hoffman, 1988). In Pakistan, the problem of salinity is complicated further by sodicity resulting from a high sodium and low calcium proportion on the soil exchange complex. Soil salinity and sodicity inhibit plant growth through inducing water stress, specific ion effect and nutrient imbalance resulting deficiency of some while toxicity of others which might cause reduction in growth and yield (Wyn Jones, 1981).

The efficiency of fertilizer nitrogen in salt-affected soils depends upon the nature and amount of fertilizer added, its mineralization pattern overtime, soil type and soil salinity/sodicity levels (Chaudhry *et al.,* 1989). Much work has been done on good lands regarding the efficient use of N, but little information is available about its economical use on salt-affected soils for sustainable rice crop production. Realizing the importance of the subject, a study was planned to determine an appropriate rate of N application for rice under salt-affected soil conditions.

MATERIALS AND METHODS

A pot experiment was conducted by using sandy clay loam soil. Soil was air-dried, ground and passed through a 2 mm sieve. Chemical analyses of the representative soil sample (EC_e 1.60 dS m^{-1}, pH_s 7.60, SAR 3.22, $CaCO_3$ 3.52%, CEC 6.50 $cmol_c$ kg^{-1}, total N 0.05%, available P 6.00 ppm, available K 108.0 ppm and organic matter 0.85%) was done by the methods described by the U.S. Salinity Lab. Staff (1954). Salinity (EC) and sodicity (SAR) were created artificially by adding $NaHCO_3$ and NaCl in the ratio of 9:1, respectively on equivalent basis. Three salinity/sodicity levels, i.e. S_1 (EC_e 5.6 + SAR 29.3), S_2 (EC_e 6.1 +SAR 44.3) and S_3 (EC_e 6.3 + SAR 55.46) were achieved. Ten kg soil was filled in each pot. Nitrogen was applied @ 100 (N_1), 125 (N_2) and 150 (N_3) mg kg^{-1} soil as ammonium sulphate. A basal dose of PK @ 45 mg kg^{-1} each as single superphosphate and potassium sulphate and zinc @ 10 mg kg^{-1} soil in the form of $ZnSO_4$ were applied in all the pots. Nursery of rice IRRI-6 was raised for thirty days without N application. One third N was applied as the basal dose while the remaining amount of N was applied in two equal splits, one at tillering stage (25 days after transplanting) and second at panicle initiation. Data on plant height, 100-grain weight and paddy yield were recorded and were subjected to statistical analysis by ANOVA technique following completely randomized design (CRD) with three repeats (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Number of tillers. The number of tillers significantly increased with the use of fertilizer N (Table I). Minimum tillers were found for N_1 (100 mg N kg^{-1} soil) which increased with increasing the dose of N. Similar trend in rice tillering was recorded by Mahmood *et al.* (1993). Number of tillers were maximum at S_1 (EC_e 1.6 dS m^{-1}, SAR 3.22) and minimum at S_3 (EC 6.3 dS m^{-1}, SAR 55.46). The application of fertilizer N increased the number of tillers even at high soil SAR and was the highest for N_3 (150 mg N kg^{-1} soil), although salinity and nitrogen interaction was statistically similar. Aslam *et al.* (1994) and Nadeem *et al.* (1995) also observed similar response of N application at different levels for wheat and rice crops, respectively. The reduction in number of tillers with increasing SAR at EC_e 6.0 dS m^{-1} might be due to specific ion effect of Na and osmotic pressure of soil solution (Magistad *et al.,* 1943). Similar reduction in number of tillers due to increasing SAR levels was found by Mahmood *et al.* (1993) for rice crop.

Table I. Crop growth as affected by soil salinity/sodicity and fertilizer nitrogen application

Nitrogen Level	EC ≈ 6.0 dS m^{-1} with SAR level				
	S_0 (3.22)	S_1 (29.3)	S_2 (44.3)	S_3 (55.5)	Mean
Number of tillers pot^{-1}					
N_1 (100 mg kg^{-1} soil)	31.66	33.66	29.66	27.66	30.66 C
N_2 (125 “)	41.66	37.00	36.00	33.00	37.08 B
N_3 (150 “)	40.66	44.00	42.10	37.00	41.91 A
Mean	39.33 A	38.22 AB	35.89 C	32.77 D	
Paddy yield g pot^{-1}					
N_1 (100 mg kg^{-1} soil)	42.66 d	39.98 e	27.15 g	21.11 h	31.97 C
N_2 (125 “)	67.31 a	46.37 d	30.48 fg	28.19 g	43.06 B
N_3 (150 “)	61.15 b	54.03 cd	36.60 e	34.36 ef	46.53 A
Mean	57.04 A	45.76 AB	31.41 B	27.88 C	
100-grain weight (g)					
N_1 (100 mg kg^{-1} soil)	2.18	1.83	1.61	1.55	1.79 C
N_2 (125 “)	2.21	2.12	1.71	1.69	1.93 B
N_3 (150 “)	2.18	2.19	1.95	1.83	2.04 A
Mean	2.19 A	2.05 B	1.76 C	1.69 C	

Values with same letter (s) are statistically similar at p = 0.05; Values in parenthesis in column titles are of soil SAR achieved

Paddy yield. The paddy yield increased significantly with increasing the dose of N fertilizer (Table I). The maximum yield (57.04 g pot^{-1}) was obtained for S_0 and minimum (27.88 g pot^{-1}) for S_3 . Such reduction in yield has been reported by Arjunan and Chandersekaran (1988). It might be due to nutritional imbalance and higher osmotic pressure induced by salts in the rooting medium (U.S. Salinity Lab. Staff, 1954). Application of fertilizer N increased yield significantly over N_1. An increase in cation exchange capacity of root (Bear, 1964) and growth dilution factor in response to nitrogen application might have played role to induce tolerance against the prevalent EC or SAR stress environment. The results are in agreement with those reported by Malik and Shah (1996) for wheat and Nadeem *et al.* (1995) for rice crops.

100-grain weight. Hundred grain weight also increased significantly with increasing doses of N (Table I). Significantly the highest 100-grain weight (46.2 g) was produced with N_3. The results are in agreement with those reported by Nadeem *et al.* (1995). As far as salinity level is concerned, statistically the highest 100-grain weight (2.19 g) was obtained for S_0 which decreased with increasing EC and SAR. The reduction in 100-grain weight with increasing salinity appears due to higher osmotic pressure and nutritional imbalance induced by soluble salts and SAR in the rooting media (U.S. Salinity Lab. Staff, 1954).

Nitrogen in paddy. The fertilizer N and salinity levels affected significantly the N concentration in paddy (Table II). Similar increase in N concentration with increasing rate of N was reported by Singandhupe and Rajput (1990) and Mahmood *et al.* (1993). The highest dose (N_3) significantly increased N concentration in paddy over all the other treatments while the lowest concentration of N was with N_1. Among salinity levels, the maximum N concentration was 1.91% with S_3 and minimum of 1.80% for S_0. This might be due to growth reduction at S_3. Salinity and N interaction affected N concentration significantly, maximum at N_2S_3 (1.96%).

Phosphorus in paddy. The P concentration in paddy increased significantly with increasing soil SAR at similar EC_e (Table II). The interaction between salinity/sodicity and N was also significant. The application of N decreased the P concentration in paddy as P was the highest (0.53%)

Table II. Per cent NPK in paddy as affected by EC + SAR and fertilizer nitrogen application

Nitrogen Level	EC ≈ 6.0 dS m^{-1} with SAR level				
	S_0 (3.22)	S_1 (29.3)	S_2 (44.3)	S_3 (55.5)	Mean
Nitrogen (%)					
N_1 (100 mg kg^{-1} soil)	1.71 i	1.79 h	1.85 e	1.91 c	1.81 C
N_2 (125 “)	1.87 d	1.78 h	1.83 f	1.84 ef	1.83 B
N_3 (150 “)	1.81 g	1.92 b	1.96 a	1.96 a	1.92 A
Mean	1.80 D	1.83 C	1.88 B	1.91 A	
P (%)					
N_1 (100 mg kg^{-1} soil)	0.45 h	0.48 g	0.59 b	0.61 a	0.53 A
N_2 (125 “)	0.44 i	0.43 I	0.56 e	0.58 c	0.50 B
N_3 (150 “)	0.40 k	0.42 j	0.56 e	0.57 d	0.48 C
Mean	0.43 D	0.44 C	0.57 B	0.59 A	
K (%)					
N_1 (100 mg kg^{-1} soil)	0.640	0.629	0.515	0.400	0.547 B
N_2 (125 “)	0.671	0.630	0.513	0.403	0.554 AB
N_3 (150 “)	0.677	0.632	0.517	0.404	0.558 A
Mean	0.663 A	0.630 B	0.514 C	0.401 D	

Values with same letter(s) are statistically similar at p = 0.05; Values in parenthesis in column titles are of soil SAR achieved with N_1 and minimum (0.48%) in case of N_3. With salinity/sodicity, the average P concentration in paddy increased by a factor of about 37% over plants grown in the normal soil (EC_e 1.60 dS m^{-1}, SAR 3.22).

potassium in paddy. Among fertilizer treatments, increasing rate of N increased the K concentration, being maximum (0.55%) in case of N_3 and minimum (0.545) with N_1 (Table II). Interaction between salinity/sodicity and N was non-significant. The maximum K concentration was found with S_0 (0.66%) and minimum (0.40%) in S_3 treatment. Similar results were reported by Yasin (1991). The K concentration in paddy decreased with soil SAR (SAR 55.46, EC_e 6.3 dS m^{-1}) by about 22% compared with that plants grown on normal soil (SAR 3.22, EC_e 1.6 dS m^{-1}). The results are in agreement with those of Rashid (1996) for rice crop. The interaction between SAR and fertilizer N remained non-significant.

CONCLUSIONS

Plant height, 100-grain weight and paddy yield increased significantly with the application of 150 mg N kg^{-1} soil at all the SAR levels at $EC_e \approx 6.0$ dS m^{-1} whereas EC_e + SAR combinations tended to decrease these parameters. Overall, it is concluded that even at higher levels of soil EC_e with SAR, fertilizer-N remained beneficial and could be exploited this approach/strategy for commercial level to better manage crop production from such soils.

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