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Nitrogen Losses and Physiological Efficiency of Rice Influenced by Nitrogen Sources under Saline Soil Condition

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Abstract: Nitrogen losses under saline soil conditions (ECe = 1.7 and 10 dS m^{-1}) and assimilation by rice crop grown in glazed pots were detected using two doses (600 and 800 mg N pot^{-1}) of urea, ammonium sulphate and their combination (1:1). Salinity of 10 dS m^{-1} in the respective pots was developed artificially by mixing NaCl. With increasing salinity, a significant reduction in N-assimilation by the crop was observed while N materials and their rates significantly retrenched the hindrance effect. Average physiological efficiency was eminent with urea and ammonium sulphate combination at both the rates. Among the N materials, maximum N losses were observed through the straight application of urea or ammonium sulphate. The mixture fertilization even at lower dose was found as effective as the high dose in abating N losses and ultimately improving N use efficiency under the salt stress of 10 dS m^{-1}.

Key words: N Sources and doses, Mixture Fertilization, Salt Stress, Rice Crop, N Losses, Physiological Efficiency, Apparent N Recovery, Pakistan

Introduction

Availability of plant nutrients in problem soils is severely limited to sustain high production of crops, especially of nitrogen due to volatilization and denitrification losses. Modern agriculture depends upon the commercial nitrogen fertilization for obtaining higher yields of crops. And about 80% of the nitrogen fertilizers is used as urea from which the risk of volatilization losses is much higher particularly under saline soil conditions due to which fertilizer use efficiency by crops is greatly affected. Only 50% of applied nitrogen is taken up by non-legume crops such as maize and wheat and only 30-40% by paddy rice (Hardy *et al*., 1975). Many research workers (Vlek and Craswell, 1981) have reported that this low efficiency is largely due to NH_3 volatilisation that is encouraged by the high pH of soil. As the nitrogenous fertilizers used contain their nitrogen as ammonical nitrogen or becomes ammonical upon hydrolysis, therefore, on problem soils the NH_3 volatilization losses might be much higher than that of normal soils (Fan and Mackenzie, 1993).

Successful crop production under saline environments demands the optimum use of plant nutrients, particularly nitrogen fertilizers, in addition to other agronomic practices. Therefore, nitrogen application and management to increase the yields from these soils seems to be important. The objective of this study was to find out the best source of nitrogen application with maximum fertilizer use efficiency and minimum nitrogen losses under adverse soil conditions.

Materials and Methods

The experiment was conducted in the net house, Saline Agriculture Research Cell, University of Agriculture, Faisalabad during the rice growth season 1990. Ten kg of air-dried and ground normal soil (ECe = 1.7 dS m^{-1}; pH = 7.9; N = 0.06%; sandy clay loam) was filled in 42 glazed pots (30 × 30 cm) and calculated amounts of NaCl (to raise Ece = -10 dS m^{-1}) salt were mixed well according to plan in the respective pots. The experiment was laid out in completely randomized design.

The various nitrogen sources and their levels were as:

F_0 = Control (No nitrogen)
F_1 = 600 mg N pot^{-1} as urea
F_2 = 800 mg N pot^{-1} as urea
F_3 = 600 mg N pot 1 as ammonium sulphate
F_4 = 800 mg N pot^{-1} as ammonium sulphate
F_5 = 600 mg N pot^{-1} as urea + ammonium sulphate
F_6 = 800 mg N pot^{-1} as urea + ammonium sulphate

A basal dose of P, K and Zn at 400, 250 and 50 mg per pot as SSP, SOP and $ZnSO_4$ was applied in all the pots including control soil. Six seedlings of rice variety KS-282 (30-day old) were transplanted in each pot. The crop was irrigated with canal water throughout the growth season. Necessary plant protection measures were followed when required. The rice crop was harvested at maturity and soil samples after the harvest of crop were also taken from each pot for the determination of nitrogen concentration by Gunning and Hibbard's method of sulphuric acid digestion using Kjeldhal flask. Gaseous losses of nitrogen were determined as:

$$N_L = (N_A + N_S)-(N_H + N_U)$$

Here,

N_L = Total Nitrogen Losses
N_A = Nitrogen Applied
N_S = Soil N already present
N_H = Soil N after Harvest of Crop
N_U = Total N uptake by Crop

Straw and grain samples collected from each treatment were analysed for the total N content to calculate Physiological Efficiency (PE) and Apparent Nitrogen Recovery (ANR) as follows:

$$PE = \frac{\text{Grain Yield}_F\text{-Grain Yield}_C}{\text{N uptake}_F\text{-N uptake}_C} \quad \text{and}$$

$$ANR = \frac{\text{N uptake}_F\text{-N uptake}_C}{\text{N uptake}_F\text{-N uptake}_C} \times 100$$

Where subscripts F and C indicates the Fertilized and Controlled treatments, respectively. The results so obtained were analysed statistically following the ANOVA technique (Steel and Torrie, 1980).

Results and Discussion

As for as N concentration in soil after the harvest of rice crop (Table 1) was concerned, average minimum soil nitrogen was determined from the control at salinity of ECe = 10 dS m^{-1}. At this salinity level, pots fertilized with high dose of N had

Table 1: Effect of N sources and salinity level on soil N after the harvest and Physiological Efficiency of rice crop (Average of three repeats)

N Source	% Soil N (after the harvest)			Physiological Efficiency		
	Control	10 dS m^{-1}	Mean	Control	10 dS m^{-1}	Mean
FO	4.72 e	2.97 f	3.85 C		-	-
F1	5.14 a	4.88 d	5.01 AB	41.25	39.95	40.60 C
F2	5.16 a	4,92 cd	5.04 A	44.18	40.12	42.15 AB
F3	5.09 b	4.88 d	4.99 B	42.06	40.26	41.16 B
F4	5.12 ab	4.98 c	5.05 A	43.46	40.83	42.15 AB
F5	5.13 a	4.97 c	5.05 A	46.86	40.42	43.64 A
F6	5.09 b	4.99 c	5.05 A	45.56	41.81	43.69 A
Mean	5.05 A	4.66 B		37.62 A	34.77 B	

Values followed by same letter(s) are statistically similar at p=0.01 level of significance

Table 2: N Losses and Apparent N Recovery by rice crop grown under saline soil condition as influenced by N sources (Average of three repeats)

N Source	Nitrogen Losses (%)			Apparent Nitrogen Recovery (%)		
	Control	10 dS m^{-1}	Mean	Control	10 dS m^{-1}	Mean
FO	0.836 e	2.839 a	1.838 A		-	
F1	0.396f	1.200b	0.7988	0.095d	0.050f	0.073 D
F2	0.170 h	1.206 b	0.688 C	0.153 b	0.071 de	0.112 B
F3	0.242g	1.114c	0.6780	0.126c	0.063e	0.095 C
F4	0.188 gh	1.085 cd	0.637 CD	0.156 b	0.080 de	0.118 Et
F5	0.150 hi	0.994 d	0.572 EF	0.134 be	0.067 e	0.101 C
F6	0.110 i	0.983 d.	0.555 F	0.171 a	0.094 d	0.133 A
Mean	0.299 B	1.346 A		0,119 A	0.061 B	

Values followed by same letter(s) are statistically similar at p=0.01 level of significance

significantly higher N concentration as compared to lower dose, except mixture fertilization at 600 mg N pot^{-1} that was statistically similar to higher dose of mixture (800 mg N pot^{-1}). The maximum concentration of 4.99, 4.98 and 4.97 g pot^{-1} was observed in the case of F6, F4 and F5 respectively which might be due to more N application and reduced volatilization losses through blended fertilization (De Datta *et al*., 1987; Hamid and Ahmad, 1988; Zia *et al*., 1992). N concentration decreased by about 11% with increasing soil salinity to 10 dS m^{-1}. This decrease in soil N at increased salinity may be attributed to its more gaseous losses of added N under saline environments which resulted in less uptake of N by the crop as well as low relation in the soil. Similar explanations has been discussed by Aslam *et al*. (1989) and Mahmood *et al*. (1994).

Among the N sources, under both non saline and saline soil condition, though the differences were non significant yet the physiological efficiency increased slightly with increasing the rate of N application under stress condition and was maximum with urea plus ammonium sulphate combination at 800 mg N pot^{-1} (Table 1). The average maximum physiological efficiency was determined with mixture fertilization even at lower dose of 600 mg N pot^{-1} which was statistically superior to the straight application through urea or ammonium sulphate just as the higher dose (800 mg N pot^{-1}) of pure fertilizers. Accordingly, the lower rate of urea plus ammonium sulphate combination has found as efficient as the higher dose of sole fertilization directly with urea or ammonium sulphate. The minimum physiological efficiency was observed with the application of urea alone at 600 mg N pot^{-1}. This may be due to less N application and more N losses from this treatment (Table 2) and ultimately minimizing N assimilation. Grewal and Kanwar (1967) observed that ammonium fertilizers increased the uptake of nitrogen by paddy crops. Similar explanations have been reported by Ventura and Yoshida (1977) and Hamid and Ahmad (1987). At salinity of 10 dS m^{-1} the average physiological efficiency was reduced by about 8% as compared to that from the normal soil. This reduction with increasing level of salinity might eventually be due to nutritional imbalance created by the added NaCl salt. There were number of reasons as to why physiological efficiency decreases under saline conditions. Many research workers (Hamid and Ahmad, 1987; Aslam *et al*., 1989; Zia *et al*., 1992, 1998) have documented similar conclusions.

From the results, it is clear that efficiency of N fertilizer was maximum when N was applied as a mixture of urea and ammonium sulphate at both the rates (600 and/or 800 mg N pot^{-1}). The reason may be the minimum N losses and maximum apparent nitrogen recovery (Table 2) due to the judicious use of urea and ammonium sulphate combination (Craswell and Godwin, 1984; De Ferrante *et al*., 1986; Hamid and Ahmad, 1988).

It is evident from Table 2 that maximum average losses of nitrogen were observed at higher salinity as compared to non-saline soil. Under saline soil condition minimum losses were detected from the fertilizer treatments where N was applied as a mixture of urea and ammonium sulphate in 1:1 ratio. It is interesting to note that the combination of urea and ammonium sulphate even at lower rate has found to be superior significantly than the straight application of urea or ammonium sulphate. It indicates that the depressive effect of ammonium sulphate was partially offset by improving the fertilities status through the sound use of mixture fertilization. From the fertilized treatments, maximum N losses were determined in the case of urea trough straight application at both the rates. The combination of urea and ammonium sulphate was found to be the most effective source in minimizing N losses. It might be due to slow decomposition of urea and stimulation of to be the most effective source in minimizing N losses. It might be due to slow decomposition of urea and stimulation of nitrification by ammonium ions released from ammonium sulphate resulting in suppression of ammonium losses from urea. Reddy arid Patrick (1980), Whitehead and Raistrick (1990), Fan and Mackenzie (1993) and Mahmood *et al*. (1994) concluded similar findings.

The average apparent N recovery in rice crop was significantly higher under both saline and non saline soil conditions with the treatment of mixture fertilization at 800 mg N pot^{-1} (Table 2). At higher salinity apparent N recovery decreased significantly by about 49% as compared to that from control soil. The reduction in apparent N recovery was improved significantly through N fertilization, particularly by mixture fertilization. As it has been discussed earlier, the lower efficiency of straight fertilization through urea or ammonium sulphate compared with urea plus ammonium sulphate combination (1:1) is understandable, because the major part of N from urea under reduced saline soil condition is volatilized as NH_3 (Hamid and Ahmad, 1987) however, on the other hand, through mixture fertilization, improvement in apparent nitrogen recovery might be due to slow decomposition of urea and stimulation of nitrification by ammonium ions released from ammonium sulphate resulting in suppression of N losses from urea. Since, it is clear from the data, that minimum N losses were detected from mixture fertilization even at lower rate, which conclusively resulted in enhancing apparent nitrogen recovery. Zia *et al*. (1992) have reported similar elucidations.

On the basis of this study, it could thus be inferred that apparent nitrogen recovery and physiological efficiency of rice crop can be improved through the blended application of urea and ammonium sulphate (1:1) in the salt-affected soil.

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