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Effect of Nitrogen Levels on Yield of and Nutrient Uptake by Salt-tolerant Rice and Wheat Cultivars in Gypsum-amended Sodic Soils

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Abstract: The effect of nitrogen levels on yield of and nutrient uptake by salt-tolerant rice and wheat cultivars in a gypsum-amended sodic soil of Uttar Pradesh was studied at the Central Soil Salinity Research Institute, Regional Research station, Lucknow. The promising results reveal that the salt-tolerant rice variety CSR 13 gave 75.5% and 116.0% higher grain yield over traditional salt-tolerant variety Bejhari with 120 and 150 kg N ha^{-1}, respectively. Similarly salt-tolerant variety of wheat KRL 19 gave 13.0% higher grain yield over KRL 1-4 with 150 kg N ha^{-1}. Maximum agronomic response was found in CSR 13 with 120 kg N ha^{-1} and it decreased with the increase in N level but in traditional variety Bejhari response to N reduced drastically with the increasing levels of N. In wheat, both the varieties responded with increasing levels of N up to 120 kg ha^{-1}. Maximum net return and benefit:cost ratio was obtained from salt-tolerant rice (CSR 13) and wheat (KRL 19) cultivars grown with 150 kg N ha^{-1}.

Key words: Nitrogen levels, salt-tolerant rice and wheat cultivars, yield, N uptake, N use efficiency

India is endowed with 8.6 million ha (Mha) salt affected soils (Singh 1992), out of this, area under alkali soils is 2.5 Mha (Abrol and Bhumbla 1971). As per current estimates, India incurs 12% loss to the production system due to soil degradation (Singh *et al.* 2000). Uttar Pradesh has the largest area of 1.20 Mha under salt-affected soils. Rice-wheat is the most widely used cropping system in the reclaimed sodic soils occupying about 60-70% of the total reclaimed land in Uttar Pradesh. The farmers are using marginally salt-affected soils for double crops where good quality irrigation water is available, monocropping in the moderately affected areas in a good monsoon year and the severely-affected area is always kept fallow. The crops grown on these soils invariably suffer from nutritional disorder resulting in low yields. Productivity of rice and wheat under these reclaimed soils is about 2.1 and 1.8 t ha^{-1}, respectively. The causes of low productivity are poor fertility status, imbalanced use of fertilizers and cultivation of traditional varieties with poor management practices. Alkali soils are low in organic matter and hence poor in total and available N content (Singh *et al.* 1983). Hydrolysis of urea, the most commonly used nitrogenous fertilizer in these soils is slower than that in normal soils (Nitant and Bhumbla 1974). Kumar *et al.* (1995) observed that nearly 10-60% of the applied N was lost through volatilization in these soils. In the recent past, several salt-tolerant varieties of rice and wheat have been developed which might be differentially responsive to nitrogen fertilization and also differ in reclaiming properties (Mishra *et al.* 1992). The area-specific N requirement for salt-tolerant varieties of rice and wheat is not available for the reclaimed and partially reclaimed sodic soils of Uttar Pradesh. Therefore, the present study was undertaken to find out the effect of N levels on crop phenology, nutrient uptake and optimum levels of N for salt-tolerant rice and wheat cultivars for maximizing the yields and to identify the suitable salt-tolerant rice and wheat cultivars for the gypsum-amended alkali soils.

Materials and Methods

A field experiment was conducted during three consecutive years of 2001-02, 2002-03 and 2003-04 on highly alkali soils (pH 10.4, EC_2 >2.0 dS m^{-1}, ESP > 85 and G.R 30.7 t ha^{-1}), low in organic carbon (0.08%), medium in available P (19.5 kg ha^{-1}) and rich in K (388 kg ha^{-1}) at the Central Soil Salinity Research Institute. Regional Research station, Lucknow located at 48°26′ N and 46°80′ E. On the basis of calculated gypsum requirement (G.R), a uniform dose of gypsum @ 15.35 t ha^{-1} *i.e.* 50% G.R.

was applied in all the treatments before imposing the N treatments and transplanting of rice. Thirty days after application of gypsum, rice as first crop was transplanted during first week of July. The experiment was laid in a split plot design with 5 levels of nitrogen (0, 60, 90, 120 and 150 kg ha^{-1}) in main plots and 2 salt-tolerant varieties of (CSR 13 and Bejhari) and wheat (KRL 19 and KRL 1-4) in sub-plots with 3 replications. A uniform dose of P @ 60 kg ha^{-1} through single superphosphate and 25 kg zinc sulphate ha^{-1} was applied as basal in rice. However, zinc sulphate was not applied to wheat. Half of the dose of N and full dose of P were applied as basal at the time of transplanting of rice and sowing of wheat as per treatment. The remaining half dose of N was applied in two equal splits at 3 and 6 weeks after transplanting of rice and at crown root initiation (CRI) and tillering stages in wheat. All the recommended agronomic and cultural practices for growing of rice and wheat in alkali soils were followed.

Five hills in each plot were randomly selected and tagged for recording the plant height and number of tillers $hill^{-1}$. Similarly in wheat plant height was recorded from the tagged plants and number of tillers/ m row length was taken from three different marked places in the plot. For dry matter accumulation 5 hills/ plot were cut from ground level from the second row and dried in a hot air oven at 60 ^{0}C to a constant weight. The net plots were harvested and sun-dried for 4 days in the field and total biomass yield was recorded. After threshing, cleaning and drying the grain yield was recorded. Straw yield was obtained by subtracting grain yield from total biomass yield. To find out the agronomic and physiological response (Bock 1984) of rice and wheat to applied fertilizer were computed as per following expressions:

Agronomic response (kg grain kg^{-1} N =

$$\frac{\text{Grain yield (F)} - \text{grain yield (C)}}{\text{Fertilizer N applied}}$$

Physiological response (kg grain kg^{-1} N) =

$$\frac{\text{Grain yields (F)} - \text{grain yield (C)}}{\text{Fertilizer N applied}}$$

where, 'F' is fertilized plot and "C' is control plot.

After the harvest of crop, surface soil samples from 0-15 cm depth were collected and processed for the measurement of total N content (Bremner and Mulvaney 1982) and uptake was calculated. The apparent N recovery was worked out as follows (Sharma and Prasad 1990):

Apparent N recovery (%) =

$$\left[\frac{\text{Uptake in treated plot} - \text{uptake in control plot}}{\text{Fertilizer dose}}\right] \times 100$$

The data were analyzed statistically as per Panse and Sukhatme (1967). In order to explore the economic feasibility of the project, the cost of cultivation was worked out taking into account the variable cost and the return was calculated on the basis of market prices prevailed during the study period.

Results and Discussion

Plant Growth Characters

The plant height of both the varieties increased significantly with the increasing levels of N but the difference between 120 and 150 kg N ha^{-1} was not significant. Number of tillers $hill^{-1}$ and dry matter accumulation in both the varieties increased with every increasing levels of N but in case of Bejhari, there was no significant difference in number of tillers beyond 90 kg N ha^{-1}. As regard the performance of varieties, traditional salt-tolerant variety of rice (Bejhari) attained significantly higher plant height and dry matter accumulation than CSR 13 at every level of N, whereas CSR 13 produced significantly higher number of tillers $hill^{-1}$. Behra (1998) and Dwivedi *et al*. (2000) also reported significant increase in plant height and number of tillers due to increase in N levels. In wheat, all the growth characters increased significantly with the increasing levels of N. As regards the performance of varieties , salt-tolerant variety of wheat KRL 19 was significantly superior in respect of all the growth parameters at all the N levels over KRL1-4 except plant height (Table 1).

Grain and Straw Yields

Application of N significantly enhanced the grain and straw yield of both rice and wheat crops. On the basis of 3 years pooled analysis, the grain and straw yield of rice (CSR 13) increased significantly with the increasing levels of N from 60 kg ha^{-1} to 150 kg N ha^{-1}. However, the traditional sodicity-tolerant variety Bejhari gave significantly higher grain and straw yield up to 120 kg N ha^{-1} and beyond that there was reduction in grain yield due to excessive vegetative growth and lodging of crop (Table 2). Increase in grain yield of CSR 13 was 75.5 and 116.0% over traditional salt-tolerant variety Bejhari with 120 and 150 kg N ha^{-1} respectively. Response of rice *cv.* CSR 13 varied from 51.3 to 173.0% and of traditional salt-tolerant variety Bejhari from 33.6 to 86.4% over control. The straw to grain ratio in CSR 13 decreased from 3.21 in control to 2.29, 1.99, 1.65 and 1.57 at 60, 90, 120 and 150 kg N ha^{-1} levels, respectively. However, in traditional variety Bejhari (being tall in

Table 1. Effect of nitrogen levels on plant height, number of tillers, dry matter accumulation of rice (3 years pooled)

N levels (kg ha^{-1})	Rice						Wheat					
	Plant height (cm)		Number of tillers hill^{-1}		Dry matter accumulation hill^{-1}		Plant height (cm)		Number of tillers rm^{-1}		Dry matter accumulation 30 cm^{-1}	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
0	84.5	101.6	7.4	6.1	26.6	33.3	60.9	53.7	46.4	42.7	37.9	26.5
60	101.0	130.5	9.0	9.6	35.9	43.6	67.1	68.7	54.1	48.7	44.4	40.8
90	103.8	147.7	10.4	10.6	43.5	53.9	72.3	71.5	58.4	55.1	55.1	48.8
120	112.5	162.1	11.1	11.4	48.5	63.1	75.2	76.3	65.7	60.3	59.8	56.9
150	118.0	166.6	13.3	11.6	55.0	64.8	80.2	79.4	73.1	68.1	65.8	63.5
CD(P=0.05)												
N	10.42		1.57		4.77		3.58		4.99		3.34	
V	5.60		NS		2.56		1.93		2.68		1.80	
N×V	12.52		NS		5.73		4.31		NS		4.02	

Rice: V_1- CSR 13, V_2-Bejhari; Wheat: V_1- KRL 19, V_2-KRL1-4

Table 2. Effect of nitrogen levels on grain yield, straw yield and N applied efficiency of salt tolerant rice and wheat cultivars (3 years pooled)

N levels (kg ha^{-1})	Rice						Wheat					
	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Apparent N recovery (%)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Apparent N recovery (%)	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
0	1.85	1.40	5.95	5.43	-	-	1.50	1.09	2.29	1.67	-	-
60	2.80	1.87	6.43	5.93	32.3	21.2	1.99	1.68	3.01	2.17	22.6	20.0
90	3.74	2.28	7.45	5.93	45.4	26.5	2.47	2.03	3.29	2.38	30.5	25.5
120	4.58	2.61	7.56	8.66	50.9	39.9	3.06	2.79	4.15	3.34	35.8	33.6
150	5.05	2.34	7.97	7.11	50.4	28.5	3.40	3.01	4.20	3.62	35.1	33.1
CD(P=0.05)												
N	0.19		1.30		2.83		0.25		0.57		1.24	
V	0.20		NS		NS		0.16		0.28		4.10	
N×V	0.44		NS		4.34		NS		NS		NS	

nature) straw to grain ratio recorded was 3.87 in control and 3.17, 2.60, 3.31 and 3.03 at 60, 90, 120 and 150 kg N ha^{-1}, respectively. The results confirm the findings of Padmavathi (1997) and Dwivedi *et al.* (2000). Salt-tolerant rice variety CSR 13 yielded 89.0% higher grain yield than the traditional variety Bejhari. The grain yield of wheat KRL 19 increased by 32.7 to 127.0% over control due to the increase in levels of N from 60 to 150 kg ha^{-1}, respectively. However, the salt-tolerant variety KRL 1-4 gave 54.1, 86.2, 157.0 and 211.0% higher grain yield over control. Salt-tolerant wheat variety KRL 19 gave 13.0% higher grain yield over KRL 1-4 under 150 kg N ha^{-1} (Table 2). The increased grain yield due to N application was attributed directly to significant improvement in the yield attributes like length of panicles, number of grains panicle^{-1} and test weight. These findings are in accordance with those of Kumar *et al.* (1994).

Nitrogen Response

The agronomic response of both the salt-tolerant rice cultivars to applied N was higher at 120 Kg^{-1} N ha^{-1}. Further increase in N level to 150 kg ha^{-1} resulted in a significant decrease in agronomic response. Maximum agronomic response (22.75 kg grain kg^{-1} N) was recorded with CSR 13 whereas, traditional salt-tolerant variety Bejhari gave very poor response (10.08 kg grain kg^{-1} N). The physiological response of CSR 13 and Bejhari to applied N at 60 kg ha^{-1} was 42.79 and 35.66 kg grain kg^{-1} N and increased significantly to 46.24 and 36.83 kg grain kg^{-1} N at 90 kg ha^{-1} N level (Table 3). Further increase in N level to 150 kg ha^{-1} resulted a significant decrease in physiological response. Similar trend in case of agronomic and physiological responses to applied N in wheat was observed in case of both the salt-tolerant varieties Maximum agronomic response (14.16 kg grain kg^{-1} N) and physiological response (42.17

Table 3. Effect of N levels on N uptake and response to N on salt-tolerant rice and wheat cultivars (3 years pooled)

N levels (kg ha^{-1})	Rice						Wheat					
	N uptake (kg ha^{-1})		Agronomic response (kg grain kg^{-1} N)		Physiological response (kg grain kg^{-1} N)		N uptake (kg ha^{-1})		Agronomic response (kg grain kg^{-1} N)		Physiological response (kg grain kg^{-1} N)	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
0	38.6	24.5	-	-	-	-	29.0	20.6	-	-	-	-
60	50.0	38.0	15.8	5.2	42.8	35.6	42.6	32.5	8.2	9.8	36.1	39.2
90	79.5	48.7	21.0	9.7	46.2	36.8	56.5	43.6	10.2	10.4	35.3	40.9
120	99.8	72.7	22.7	10.1	44.6	25.3	72.0	60.8	13.0	14.2	36.3	42.2
150	114.2	67.6	21.3	6.5	42.3	22.0	81.7	70.2	12.8	12.8	36.4	38.7
CD (P=0.05)												
N	7.27	6.41	0.65	0.65	1.20	0.98	8.47	6.32	1.50	2.10	0.85	1.20

kg grain kg^{-1} N) was obtained in KRL1-4 whereas, KRL 19 gave 13.00 and 36.43 kg grain kg^{-1} N agronomic and physiological responses, respectively. Sarkar *et al.* (1994) have observed the similar trend of variation in the agronomic and physiological response of rice and wheat to the varied levels of N. Thus, the economic optimum dose of N for salt-tolerant variety CSR 13 is 150 kg ha^{-1}; however, the traditional sodicity-tolerant variety Bejhari responded only up to 120 kg N ha^{-1} and beyond that there was severe lodging in crop resulting reduction in yield. However, for high yielding salt-tolerant variety of wheat KRL 19, 120 kg N ha^{-1} was found economical.

Nitrogen Uptake

The data on N uptake showed significant response to 150 kg N ha^{-1}. Similar to the grain and straw yields, N uptake by both rice and wheat increased significantly with the increasing levels of N. The increment of N uptake in CSR 13 with 150 kg N ha^{-1} was 46.3% higher over traditional salt-tolerant variety Bejhari with 120 kg N ha^{-1}. Both the varieties produced highest total biomass yield under these treatments. In wheat, N uptake by KRL 19 was 16.5% higher over KRL 1-4 with 150 kg N ha^{-1}. The maximum N uptake by wheat during all the three consecutive years was recorded with KRL 19 (Table 3). The increment in N uptake was probably due to improvement in soil conditions, which encouraged the proliferation of roots and improved synchrony between supply and plant demand, which in turn drew more nutrients from larger area and greater depth (Kumar *et al.* 1996; Minhas and Sood 1996).

Nitrogen Recovery

The apparent N recovery from CSR 13 ranged from 32.30 to 50.40% and from traditional variety Bejhari it was 22.00 to 39.87%. The maximum N recovery (51.0%) in CSR 13 and Bejhari was obtained with 120 kg N ha^{-1} and beyond this N level, there was a significant reduction in N recovery in traditional variety Bejhari. It might be due to reduction in grain and straw yield with increasing levels of N. Similar trend was reported in the All India Coordinated Research Project on Long Term Fertilizer Experiment in rice (Nambiar 1994). The KRL 19 variety of wheat gave highest apparent nitrogen recovery (35.79%) with 120 kg N ha^{-1} whereas, KRL 1-4 responded up to 150 kg N ha^{-1} but the difference between these two was not significant. Similar trend was also observed in KRL 1-4. The nitrogen recovery of KRL 19 was 6.54% higher over KRL 1-4 with 120 kg N. However, with 150 kg N ha^{-1}, the nitrogen recovery in KRL 19 was 6.20% higher over KRL 1-4.

Soil Improvement

In general, soil pH_2, EC and ESP after cultivation of rice-wheat cropping system in the salt-affected soils decreased because of submergence and biological activities of the rice roots. The reduction in EC with increasing levels of N was not much affected due to N application but it reduced due to decomposition of higher amount of crop residues remaining in the soil after harvesting of the crops (Table 4). The observed reduction in soil pH_2 was due to acid formation during decomposition of crop root residues and submergence of rice crop. Reduction in exchangeable Na^+ with increasing levels of N was because of the increasing cross sectional area of conducting pores due to rice cultivation, resulting in increased permeability. Chhabra and Abrol (1977) opined that rice roots provide channels for the movement of water, which increase permeability and help in leaching of salts. The increase in soil organic carbon content to increasing levels of N over the

Table 4. Effect of fertilizer levels and varieties on soil properties after 3 years of rice-wheat rotation

N levels (kg ha^{-1})	pH_2		EC (dS m^{-1})		O.C. (%)		ESP		Available N (kg ha^{-1})	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
0	9.23	9.02	0.32	0.30	0.18	0.19	36.0	36.4	99.6	95.2
60	9.02	8.93	0.21	0.64	0.21	0.19	36.8	37.2	132.6	125.6
90	8.77	8.89	0.41	0.44	0.22	0.19	34.0	34.2	138.5	130.2
120	8.71	8.90	0.26	0.25	0.22	0.19	32.8	33.7	144.6	147.8
150	8.64	8.87	0.28	0.24	0.24	0.21	30.2	33.1	140.2	123.3
Initial level	10.36		1.43		0.11		39.0		94.0	

Table 5. Effect of nitrogen levels on gross returns, net returns and benefit: cost (B:C) ratio of salt-tolerant rice and wheat cultivars

Treatments	Gross return (Rs ha^{-1})			Net return(Rs ha^{-1})			B:C ratio
	2001	2002	2003	2001	2002	2003	
N_0V_1	20466	20651	25513	-19215	2626	6533	0.87
N_0V_2	16683	15308	18222	-22998	-2717	-758	0.66
$N_{60}V_1$	36299	37091	38829	-7038	15214	16010	1.27
$N_{60}V_2$	24197	21249	24266	-19210	-628	1447	0.79
$N_{90}V_1$	39944	41935	43734	-4020	19432	20178	1.39
$N_{90}V_2$	31700	25810	26973	-12264	3307	3417	0.94
$N_{120}V_1$	47650	48632	49908	3058	25501	25788	1.59
$N_{120}V_2$	36727	33779	34239	-7865	10648	10719	1.14
$N_{150}V_1$	53511	53525	55050	8293	29718	30190	1.72
$N_{150}V_2$	38170	34341	35912	-7048	10534	11052	1.15

V_1-CSR 13 and KRL 19
V_2-Bejhari and KRL1-4

initial levels may be attributed to better root growth of rice and wheat and subsequent decomposition of these roots. Acharya and Rajgopalan (1956) and Biswas *et al.* (1967) have also reported improvement in the organic carbon status in sodic soils under continuous rice-wheat cropping. Available N status also improved appreciably at optimal to super optimal levels of N over the initial levels.

Economics

Pooled results revealed that maximum gross return and net returns from the rice- wheat cropping system were obtained with 150 kg N ha^{-1} where CSR 13 of rice and KRL 19 of wheat were grown; however, these were drastically reduced with traditional salt-tolerant variety of rice Bejhari and KRL 1-4 of wheat. Similar trend was also observed at 60, 90 and 120 kg N ha^{-1} levels. Higher benefit: cost ratio (1.72) for three years under rice-wheat rotation with CSR 13 of rice and KRL 19 of wheat was also recorded with 150 kg N ha^{-1}.

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