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Response of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) to gypsum rates in sodic soils*

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Out of 6.73 million ha salt affected soils in the country (NRSA and Associates 1996) about 3.8 million ha is sodic soil. Uttar Pradesh is having the largest area (1.36 million ha) under sodic soils. For the reclamation of sodic soils, gypsum ($CaSO_4 2H_2O$) is generally recommended. With the available chemical amelioration technology, the cost of reclamation of sodic land is more than Rs 40, 000/ha (Dutta *et al.* 1996) because of high cost of gypsum. Application of farmyard manure @ 30 tonnes/ ha alone or 20 tonnes/ha in conjunction with gypsum @ 25% gypsum requirement may not be feasible due to the non-availability of farmyard manure in such a huge quantity. Under these situations, adoption of costly technology for reclaiming the sodic soils by the resource poor farmers may not be a viable proposition. In the above context there is need to develop low-cost sodic soil reclamation technology that suits the resource poor small and marginal farmers.

A field experiment was conducted at Regional Research Station, Central Soil Salinity Research Institute, Lucknow during 2001–02, 2002–03 and 2003–04. The soil site was highly sodic having PH_2 10.5, EC_2 1.43 dS/m, organic carbon 0.80 g/ kg, $CaCO_3$ 2.41%, sandy loam in nature, poor in nitrogen (94 kg/ ha) medium in phosphorus (25 kg/ ha) and rich in potash (237 kg/ ha). The gypsum requirement (GR) of the experimental site was determined by Schoonover (1952) method prior to the layout of the experiment during 2001–02 was 30.8 tonnes/ha. The irrigation water applied to the crop was having RSC< 2.50 me/litre and SAR< 2.14 me/ litre. Experiment was laid out in a split-plot design and replicated 4 times comprising 4 rates of gypsum (0, 15, 25 and 50% of gypsum requirement) in the main plots and 2 varieties of each sodicity tolerant (V_1) 'CSR 13' of rice (*Oryza sativa* L.) and 'KRL 19' of wheat (*Triticum aestivum* L. emend. Fiori Paol.) and traditional high-yielding varieties (V_2) 'Pant 4' of rice and 'PBW 343' of wheat in sub-plots. As per treatments gypsum was incorporated in the soil to a depth of 10 cm. The rice was transplanted at 20 cm × 15 cm apart, however in wheat row-to-row spacing was 20 cm. The recommended rate of nitrogen @ 150 kg /ha and zinc sulphate @ 25 kg/ ha for rice and 150 kg N/ ha for wheat were applied. The soil was having sufficient available phosphorus and potash and hence no phosphorus and potash were applied to the crops. Half the rate of nitrogen and full rate of $ZnSO_4$ were applied as basal in rice and wheat. The remaining half rate of N was applied in 2 equal splits at 30 and 60 days after transplanting of rice and at 21 and 45 days after sowing in wheat. The rice and wheat were cultivated with the recommended cultural practices. In rice the growth attributes, viz. plant height and tillers/hill were measured from 5 randomly selected hills in each plot. Five plants of wheat were tagged for recording plant height and number of effective tillers at 30 days interval. Dry matter accumulation in rice was recorded from 3 hills/ plot and in wheat from 30 cm row length. The plants were cut from ground level and dried in a hot air oven at 60^0C to attain a constant weight. The net plot area (40 m^2) was harvested and yields were recorded. After harvesting of each crop, soil samples from 0–15 and 15–30 cm soil depth were collected and analyzed for soil properties, viz. *PH* (1: 2 soil : water), electrical conductivity (dS/m at 25^0C) and organic carbon (Piper 2005). Available N (Subiah and Asija 1956), P (Olsen *et al.* 1954) and K (Jackson 1973) were determined by following the standard methods. Infiltration rate was measured after harvesting of each crop using double ring infiltrometer. The statistical analysis for individual years and pooled were performed using MSTAT-C procedures.

Three years pooled data revealed that all the growth parameters, viz. plant height, number of tillers and dry matter accumulation of rice and wheat increased with increase gypsum rates up to 50% gypsum requirement. The plant height of rice increased significantly up 15% gypsum requirement and after that increment in plant height was not significant. Number of effective tillers increased significantly with every increasing rate of gypsum up to 50% gypsum requirement. The dry matter accumulation also increase with increased rate of gypsum up to 50% gypsum requirement but the difference between 25% and 50% gypsum requirement

*Short note

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rates were not significant (Table 1). In wheat also, significant difference in plant height was recorded only up to 15% gypsum requirement and thereafter plant height was not increased significantly with subsequent increase in gypsum rates. Effective tillers/ m increased significantly with every increasing rate of gypsum. However, dry matter accumulation increased significantly only up to 25% gypsum requirement. All the growth parameters of salt-tolerant variety 'CSR 13' of rice were significantly superior over the traditional high-yielding variety 'Pant 4'. However in wheat, there was no significant difference in plant height and number of tillers between the varieties. Dry matter accumulation in sodicity tolerant variety 'KRL 19' of wheat was significantly higher compared with the traditional high-yielding variety 'PBW 343'.

Panicle length in rice and spike length in wheat increased with increase in gypsum rates up to 25% gypsum requirement over 15% gypsum requirement and control in rice and wheat. Salt-tolerant varieties 'CSR 13' of rice and 'KRL 19' of wheat gave significantly higher panicle and spike length over the traditional high-yielding varieties, i e 'Pant 4' and 'PBW 343'. Grains/ panicle in rice and number of grains/ spike in wheat increased significantly with increased rates of gypsum (Table 1). Test weight of salt tolerant and traditional varieties of rice and wheat increased with increasing rates of gypsum. The test weight of rice and wheat increased significantly up to 25% gypsum requirement and after that there was no significant difference in this character. Salt-tolerant varieties 'CSR 13' of rice and 'KRL 19' of wheat gave significantly higher number of grains/ panicle and number of grains/ spike-respectively over the traditional high yielding varieties. The test weight of traditional high-yielding variety of rice ('Pant 4') was higher than the sodicity-tolerant variety ('CSR 13') because of bolder grain size. However in wheat there was no significant difference in test weights between salt-tolerant and traditional varieties.

During first two years (2001–02 and 2002–03) of experiment, rice grain yield increased significantly up to 25% gypsum requirement and beyond that there was no significant difference. Chhabra *et al.* (1989) have also reported non-significant different difference in rice grain yield between 25 and 50% GR rates. However during third year of experiment (2003–04) significant difference in grain yield was recorded up to 50% gypsum requirement (Table 2). The response of gypsum on grain yield of wheat was similar to that of rice. Three years pooled analysis revealed that the grain yield of wheat increased significantly up to 50% gypsum requirement. Swarup and Singh (1993) have also reported the significant increase in grain yield of wheat with increasing level of gypsum. The increase in rice and wheat yields with increase in gypsum dose was attributed to reclamation of sodic soils with decrease in PH_2, ESP and increase in organic carbon. Salt-tolerant variety 'CSR 13' rice gave significantly higher grain yield over the traditional high-yielding variety 'Pant 4'. The mean increase in grain yield of salt-tolerant variety 'CSR 13' was 30% over traditional high-yielding variety 'Pant 4' Mishra *et al.* (1992) have also reported that the salt-tolerant varieties of rice yielded higher up to *p*H 10.2 while most of the rice varieties failed beyond *p*H 9.8. Salt tolerant 'KRL 19' variety has also gave slightly higher grain yield (5%) over three years than the traditional high-yielding variety 'PBW 343'.

Table 1 Effect of gypsum rates and varieties on growth and yield parameters of rice and wheat (pooled data of 3 years)

Treatment	Rice						Wheat					
	Plant height (cm)	Effective tillers/ hill	Dry matter (g/ hill)	Length of panicle (cm)	Grains/ panicle	Test weight (g)	Plant height (cm)	Effective tillers/ m	Dry matter (g/ 30 cm)	Spike length (cm)	Grains /spike	Test weight (g)
Gypsum rates (%GR)												
0	62.0	3.8	22.6	15.8	29.6	17.6	32.8	11.4	13.8	6.9	24.2	19.2
15	93.1	6.9	51.9	22.0	92.4	22.8	61.2	58.8	38.0	7.3	38.6	32.0
25	98.2	8.1	64.7	24.3	126.2	24.8	67.8	79.0	45.6	9.5	41.7	34.3
50	104.2	9.8	68.3	25.6	137.4	25.8	71.6	83.0	54.6	9.8	43.7	37.1
SEm ±	5.21	0.34	1.67	1.06	1.76	0.67	3.66	2.02	1.32	0.53	1.80	1.45
CD (*P*=0.05)	16.52	1.09	5.29	3.36	5.72	1.91	10.83	6.42	4.02	1.68	5.71	4.60
Varieties												
V_1	94.2	8.4	55.8	24.8	103.1	20.7	58.3	57.7	39.1	9.2	39.6	30.6
V_2	84.6	6.0	47.9	20.7	89.7	24.8	58.4	58.4	36.9	8.6	34.5	30.6
SEm ±	1.70	0.22	0.87	0.53	1.54	0.60	0.37	0.83	0.53	0.14	0.93	0.56
CD (*P*=0.05)	4.69	0.61	2.65	1.65	4.71	1.65	NS	NS	1.71	0.40	2.74	NS

V_1, Salt-tolerant varieties; V_2, traditional high-yielding varieties

Table 2 Effect of gypsum rates and varieties on grain yield of rice and wheat

Treatment	Rice yield (tonnes/ ha)				Wheat yield (tonnes/ ha)			
	2001	2002	2003	Pooled	2001	2002	2003	Pooled
Gypsum rates (%GR)								
0	0.20	0.45	0.53	0.36	0.19	0.27	0.43	0.21
15	2.15	3.04	2.90	3.00	1.20	1.33	1.71	1.57
25	3.93	4.40	4.22	4.40	2.12	2.32	2.62	2.50
50	4.30	4.70	4.96	4.75	2.70	2.72	3.00	3.00
SEm ±	0.13	0.15	0.12	0.09	0.17	0.14	0.10	0.07
CD(*P=0.05*)	0.43	0.47	0.37	0.29	0.57	0.53	0.29	0.23
Varieties								
V_1	3.00	340	3.30	3.40	1.62	1.76	2.02	1.87
V_2	2.30	2.91	3.00	2.81	1.48	1.56	1.86	1.77
SEm ±	0.07	0.06	0.05	0.04	0.16	0.13	0.16	0.06
CD (*P=0.05*)	0.24	0.19	0.17	0.11	NS	NS	NS	NS

V_1, Salt-tolerant varieties; V_2, traditional high-yielding varieties

After three years of study the PH_2 of surface soil (0–15 cm) reduced from 10.5 to 8.8 where the gypsum was applied @ 50% of gypsum requirement whereas, with 25% gypsum requirement PH_2 reduced to the level of 9.1. In control treatment where no gypsum was applied and only rice – wheat cropping system was followed, the PH_2 of surface soil reduced to 9.8. The results are in conformity with the findings of Swarup and Singh (1993). Maximum reduction in ESP, i e from 85 to 42 was observed with 50% gypsum requirement rate but the difference between 25 and 50% gypsum requirement rates was very less.. The organic carbon content increased from 0.80 to 1.20 g/ kg with increasing rate of gypsum up to 50% gypsum requirement because of increasing root dry biomass. The basic infiltration rate increased to 19.3 mm and 11.3 mm/day at 50 and 25% gypsum requirement rates, respectively, over the control (4.8 mm/ day) where no gypsum was applied (Table 3). Acharya and Abrol (1991) have reported tremendous improvement in soil infiltration with the addition of gypsum in sodic soils.

The improvement in soil properties either growing of salt-tolerant varieties or high-yielding traditional varieties of rice and wheat was not much affected. The synergistic effect of gypsum and salt-tolerant varieties of rice and wheat on reduction in PH_2 and ESP and increasing in organic carbon content of surface soil (0–15cm) was slightly better than the traditional high-yielding varieties of rice and wheat. This might be due to generation of more organic acids by the salt-tolerant varieties that mobilize the soil calcium.

SUMMARY

A field experiment was conducted during 2001–02 to 2003–04 to study the response of rice and wheat to gypsum rates in sodic soils. From the study it revealed that the growth and yield of rice and wheat increased with increasing rate of gypsum but significant response in these parameters was observed only up to the rate 25% gypsum requirement and beyond that there was no significant response on growth and yield of rice and wheat crops. Though the grain yields of sodicity-tolerant and traditional high-yielding varieties of rice and wheat were higher with 50% gypsum requirement rate but the differences between 25 and 50% gypsum requirement rates were not significant. Salt-tolerant variety 'CSR 13' of rice and 'KRL19' of wheat gave 30 and 5% higher grain yields over traditional high-yielding varieties 'Pant 4' rice and 'PBW 343' wheat respectively. The PH_2 and ESP of surface soil (0–15 cm) decreased with increasing gypsum rates. Increasing rate of gypsum increased the infiltration rate to the levels of 19.3 mm and 11.3 mm/ day at 50 and 25% gypsum requirement rates, respectively over the control (4.8 mm/ day). It can be concluded that under the resource scarce situation cultivation of salt-tolerant varieties of rice ('CSR 13' or 'CSR 23' or 'CSR 27') and whe at ('KRL 1-4' or 'KRL 19's) with reduced dose of gypsum @ 25% gypsum requirement ensures higher productivity than the prevailing technology, i e cultivation of traditional

Table 3 Effect of gypsum rates and varieties on improvement of soil properties after 3 years of study

Gypsum rates (%GR)	Soil pH_2 (0–15cm depth)		ESP		Organic carbon (g/ kg)		Infiltration rate (mm/ day)	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
0	9.8	10.0	64	64	0.90	0.86	4.8	4.5
15	9.3	9.4	55	57	0.92	0.90	7.0	6.0
25	9.1	9.2	48	50	1.00	1.00	11.3	11.0
50	8.8	9.0	42	43	1.20	1.20	19.3	18.5
Initial	10.5		85		0.80		2.0	

varieties after application of gypsum @ 50% gypsum requirement.

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