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Combined effect of reduced dose of gypsum and salt tolerant varieties of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) on rice-wheat cropping system in sodic soils

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ABSTRACT

A field experiment was conducted at Lucknow in Uttar Pradesh during 2001-2002 to 2003-04 on a fine loamy, mixed, hyperthermic, sodic soil having high pH, low electrical conductivity, high exchangeable sodium percentage and very low water permeability to find out the combined effect of reduced dose of gypsum and salt tolerant varieties of rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) on productivity of rice - wheat cropping system in sodic soil. This study revealed that application of gypsum @ 25% gypsum requirement (G.R.) and growing of salt tolerant varieties of rice 'CSR 13' and wheat 'KRL 19' significantly increased the yield attributes and yields of these crops in the system over control treatment as well as 15% G.R. So much so it was at par with 50% G.R. with non- salt tolerant varieties. The magnitude of combined effect of reduced dose of gypsum and salt tolerant varieties was reflected as 17 and 8.2% increase in grain yield over their counterpart varieties. Interaction between gypsum levels and salt-tolerant varieties on grain yields indicated that gypsum @ 25% G.R. with sodicity tolerant varieties in rice-wheat cropping system could save about 43% of the total initial expenditure for the reclamation of sodic soils over the recommended dose of gypsum (50% G.R.) with non-sodicity tolerant traditional high yielding varieties. Thus, for low-cost effective technology, treating the sodic soils with reduced dose of gypsum (25% G.R.) and growing salt tolerant varieties of rice 'CSR 13' and wheat 'KRL 19' proved highly economical and sustainable technology for resource scarce situations.

Key words: Cropping system, Economics, Gypsum, Rice, Salt tolerance, Sodic soils, Wheat

Out of total salt affected soils of 6.73 m ha in India, sodic soils occupy an area of 3.77 m ha (National Remote Sensing Application Centre and Associates, 1996). The major crop production constraints in sodic soils are high pH as well as exchangeable sodium, low infiltration rate, impeded drainage and poor fertility status. Application of gypsum ($CaSO_4 \cdot 2H_2O$) @ 50% gypsum requirement (G.R.) has been recommended for rice-wheat cropping system with traditional varieties (Abrol and Bhumbla, 1979). Since cost of gypsum itself accounts for 63% of the reclamation cost, the total expenditure works out to be more than Rs 40,000/ha (Dutta and Joshi, 1994). However, more than 70% farmers who own sodic soils belong to small and marginal categories. As such the adoption of the chemical amelioration technology is highly dependent on the cost of gypsum. Despite of subsidy on gypsum, adoption of the technology is very thin because of the resource poor condition of the farmers having sodic lands. Other options to replace part of the gypsum by organic amendments viz. farmyard manure (30 t/ha) and /or press mud (10 t/ha) did not catch up because of their huge quantities required and transportation cost involved. Under the resource scarce situation, where gypsum is not easily available, combined effect of reduced dose of gypsum along with salt tolerant varieties of rice 'CSR 13' and wheat 'KRL 19' ensures more productivity. By employing this approach, the saved amount of gypsum may be utilized for reclamation of double the sodic land. The productivity of traditional varieties of rice and wheat in reclaimed sodic soils is about 2.6 and 2.1 t/ha respectively whereas the productivity of salt-tolerant varieties is about 3.6 and 2.8 t/ha. It clearly indicates that there is tremendous scope to fill this gap by the synergy of reduced gypsum and salt tolerant varieties. The present study was therefore undertaken to assess the feasibility of minimizing the gypsum requirement by capitalizing on salt-tolerant varieties to sustain the productivity of rice-wheat cropping system in sodic soils.

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MATERIALS AND METHODS

A field experiment was conducted at Central Soil Salinity Research Institute, Regional Research Station, Research Farm, Shivri, Lucknow, Uttar Pradesh, from 2001-2002 to 2003-2004. It is situated at an elevation of 120 m above mean sea level extending from 26^0 47' to 26^0 48'N latitude and 80^0 46'E longitude. The mean annual rainfall is 800 mm and more than 80% generally occurs during the monsoon season (July-September). Mean annual soil temperature varies from 18.6 °C during winter and 32°C during summer. The soil of the experimental field was highly sodic with pH (1:2 soil: H_2O) 10.5, EC 1.43 dS/m and ESP 89 having low organic carbon (0.80g/ kg) and available N (94 kg/ ha), medium in available P (25 kg/ ha) and rich in exchangeable K (237.44 kg/ ha) at 0-15cm soil depth. The gypsum requirement of the experimental soil was determined by Schoonover (1952) method at initiating the experiment (2001-02) and was 30.8 t/ha. The experiment was laid out in split plot design keeping 4 levels of gypsum (0, 15, 25 and 50% of G.R.) in main plots and 2 varieties salt tolerant 'CSR 13' and 'KRL 19' and non-salt tolerant traditional high yielding 'Pant 4' and 'PBW 343' each of rice and wheat in sub - plots with 4 replications. As per treatments, gypsum was incorporated once in surface soil up to 10 cm depth in June 2001 and about 10 cm water was ponded in the plots for 10 days to displace the reaction products of Ca-Na exchange down the root zone. The 35 day old seedlings of rice was transplanted at 20 cm x 15 cm spacing while wheat was drilled at row spacing of 20 cm using a seed rate of 120 kg/ha. The recommended doses of N for sodic soils *i.e.*, 150 kg/ha and zinc sulphate @ 25 kg/ha as basal to rice only and 150 kg N/ha for wheat were applied uniformly in all the treatments. Half dose of nitrogen to both rice and wheat along with full dose of zinc sulphate ($ZnSO_4$) to rice only was applied as basal and remaining half the dose of N was applied in 2 equal splits *i.e.* at 30 and 60 days after transplanting in rice and at 21days (crown root initiation) and 45 days after sowing in wheat. About 7.5 cm depth of irrigation water in rice was given 2 days after disappearance of ponded water and 6 light and frequent irrigations in wheat.

The growth attributes were measured from five randomly selected tagged hills/ plant. Dry matter accumulation was recorded from 3 hills/ plot in rice and from 30 cm row length in wheat. The net plot area ($40m^2$) was harvested and yields were recorded. Soil samples were collected after 3 years of study and analyzed to monitor the changes in soil physico-chemical properties. Double concentric infiltrometer cylinders were used to measure the infiltration rate (Brechtel, 1976). System productivity was derived by converting the wheat yield in to rice yield based on the prevailing prices of rice and wheat during the years of experimentation. The economics of different treatment combinations were calculated on the basis of existing market price of prodûce and inputs used in cultivation.

RESULTS AND DISCUSSION

Plant growth

Three years pooled data revealed that all the growth characters viz., plant height, number of tillers and dry matter accumulation of rice and wheat increased with increasing levels of gypsum up to 50% G.R. though the differences beyond 15% G.R. were not significant. Number of effective tillers increased significantly with every additional rate of gypsum up to 50% G.R. The dry matter accumulation also increased with increased rate of gypsum up to 50% G.R. but the difference between 25% and 50% G.R. rates were not significant. Similarly the difference in the dry matter accumulation at 25% and 50% G.R. was not significant (Table 1). In wheat also, significant difference in plant height was recorded only up to 15% G.R. and thereafter the increase in gypsum rates did not bring out significant differences in this character. Number of effective tillers/m and dry matter accumulation increased significantly with every increasing rate of gypsum. However, the difference between 25% and 50% G.R. was statistically not significant.

All the growth parameters of salt tolerant rice 'CSR 13' were significantly superior over the traditional high-yielding non-salt tolerant 'KRL 19'. However, in wheat, there was no significant difference in plant height and number of tillers between the varieties. Sodicity tolerant wheat 'KRL 19' accumulated significantly higher dry matter than the traditional high-yielding non-salt tolerant 'PBW 343'.

Yield attributes

Panicle length in rice increased with increase in gypsum rates up to 50% G.R. level but significant difference in this character was recorded only up to 25% G.R. level. However, number of grains /panicle differed significantly with successive increase in the levels of gypsum. Again in terms of test weight, 25 and 50% G.R. were at par between themselves but significantly superior over control and 15% G.R (Table 1). In wheat, spike length with 15% G.R. did not differ significantly from control treatment. But 25% and 50% G.R. being at par produced significantly taller spikes than former treâtments. In grain number / spike, all the levels of gypsum were superior to control but at par among themselves. Increasing gypsum levels from 15% to 50% G.R. caused significant improvement in test weight over no gypsum treatment but remained at par with each other (Table 2).

Salt tolerant varieties 'CSR 13' of rice and 'KRL 19' of wheat gave significantly higher panicle and spike length over the traditional high-yielding non-salt tolerant varieties 'Pant 4' and 'PBW 343' respectively. Similarly salt tolerant '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 (Table 2). The test weight of traditional rice 'Pant 4' was higher than the sodicity tolerant 'CSR 13' because of bolder grain size. However, in wheat there was no significant difference in test weights between salt tolerant and traditional varieties.

Yield

Application of gypsum @ 50% G.R. gave higher grain yield of rice, which was statistically on a par with that of 25% G.R. because of the similar trend in length of panicle, number of grains/ panicle and test weight (Table 1). Chhabra *et al.* (1989) have also reported non-significant difference in rice grain yield between 25% and 50% G.R. levels. However, a saving of 25% G.R. could be possible due to growing of salt-tolerant varieties of rice and wheat. Although straw yield with 50% G.R. was highest because of higher plant height and dry matter accumulation but the difference between 25% and 50% G.R. levels was not statistically significant. Three years pooled analysis revealed that the grain yield of wheat increased significantly with increasing levels of gypsum (Table 2). The highest grain yield (2.97 t/ha) was recorded in the treatment where gypsum was applied @ 50% G.R. because of higher spike length and number of grains/spike. Swarup and Singh (1993) have also reported significant increase in grain yield of wheat with increasing levels of gypsum. The increase in wheat yield with increase in gypsum dose was attributed to reclamation of sodic soils with decrease in soil pH and ESP and increase in organic carbon. Similar trend was also recorded in straw yield.

Salt-tolerant rice 'CSR 13' of rice gave significantly

Table 1. Effect of gypsum levels and varieties on growth and yield of rice (pooled data of 3 years)

Treatment	Plant height (cm)	Effective tillers/hill	Dry matter (g/hill)	Panicle length (cm)	Grains /panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Gypsum levels (% Gypsum Requirement)								
0	62.1	3.80	19.70	15.81	29.62	17.60	0.36	2.35
15	93.3	6.96	44.10	21.96	92.37	22.81	2.99	6.87
25	98.2	8.16	57.60	24.34	126.25	24.88	4.35	8.68
50	104.2	9.86	61.80	25.64	137.37	25.79	4.75	9.44
SEm ±	5.2	0.34	1.67	1.06	1.76	0.67	0.16	0.32
CD (P=0.05)	16.5	1.09	5.29	3.36	5.72	1.91	0.50	1.05
Varieties								
'CSR13'	94.2	8.36	55.85	20.73	103.06	20.73	3.40	7.47
'Pant 4'	84.6	6.02	47.93	24.80	89.75	24.80	2.82	6.22
SEm ±	1.7	0.22	0.87	0.53	1.54	0.60	0.07	0.16
CD (P=0.05)	4.7	0.61	2.69	1.65	4.71	1.65	0.23	0.51

Table 2. Effect of gypsum levels and varieties on growth and yield of wheat (pooled data of 3 years)

Treatment	Plant height (cm)	Effective tillers/hill	Dry matter (g/hill)	Panicle length (cm)	Grains/ spike	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Gypsum levels (% Gypsum Requirement.)								
0	32.8	11.37	13.78	6.91	24.20	19.19	0.22	0.44
15	61.2	58.83	37.97	7.32	38.59	31.96	1.57	2.36
25	67.8	79.00	45.57	9.52	41.69	34.35	2.50	3.42
50	71.6	83.05	54.64	9.78	43.70	37.08	2.97	4.05
SEm ±	3.7	2.02	1.32	0.34	1.80	1.45	0.07	0.09
CD (P=0.05)	10.8	6.42	4.02	1.16	5.71	4.60	0.23	0.23
Varieties								
'KRL 19'	58.3	57.72	39.07	9.20	39.58	30.65	1.86	2.50
'PBW 343'	58.4	58.40	36.92	8.57	34.52	30.64	1.77	2.54
SEm ±	0.4	0.83	0.53	0.14	0.93	0.56	0.06	0.05
CD (P=0.05)	NS	NS	1.71	0.40	2.74	NS	NS	NS

higher grain and straw yield over the non-salt tolerant 'Pant 4'. The mean increase in grain and straw yields of salt tolerant 'CSR 13' was 30% and 20% respectively 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 pH 10.2 while most of the common ones failed beyond pH 9.8. The grain and straw yields of salt tolerant variety 'KRL 19' of wheat was slightly higher than traditional 'PBW 343' but the difference between them was not statistically significant (Table 2).

The interaction between gypsum levels and rice varieties was significant for grain yield in 2001 and 2003 but not in 2002. During 2001, 'CSR 13' significantly excelled 'Pant 4' in grain yield at gypsum levels from 15 to 50% G.R. However, the magnitude of difference decreased with increasing levels of gypsum. Salt-tolerant rice 'CSR 13' at 25% G.R. and 'Pant 4' at 50% G.R. gave practically similar yields. These observations indicate saving of gypsum to the tune of 25% by using salt tolerant rice variety in sodic soils (Table 3).

Table 3. Interaction effect of gypsum levels and varieties on grain yield (q/ha) of rice and wheat

Gypsum levels (% G.R.)	Rice 2001-02		Rice 2003-04		Wheat 2001-02	
	'CSR 13'	'Pant 4'	'CSR 13'	'Pant 4'	'KRL 19'	'PBW 343'
0	0.32	0.07	0.64	0.42	0.22	0.17
15	2.73	1.57	3.28	2.81	1.35	1.03
25	4.09	3.48	4.52	4.11	2.20	2.03
50	4.36	4.05	4.96	4.76	2.39	2.17
SEm ±	0.09		0.03		0.07	
CD (P=0.05)	0.27		0.28		0.21	

The interaction between wheat varieties × gypsum levels was significant only in 2001-02 with the result that salt tolerant 'KRL 19' with 25% G.R. produces similar grain yield (2.20 t/ha) as sensitive variety 'PBW 343' with 50% G.R.(2.17 t/ha)

Improvement in soil properties

After three years of rice-wheat cropping system, improvement in soil properties in terms of pH, ESP, organic carbon and infiltration rate was seen due to in combined effect of gypsum and salt tolerant varieties than the non-salt tolerant traditional high yielding varieties. This might be due to generation of more organic acids by the salt tolerant varieties that mobilize the soil calcium. Treating the plots with 25% G.R. and growing salt tolerant rice 'CSR 13' and wheat 'KRL 19' in sequence for 3 years reduced pH_2 of surface soil from 10.5 to 9.1 and ESP from 85 to 48 though the maximum reduction in pH_2 from 10.5 to 8.8 and ESP from 85 to 42 occurred under 50% G.R. with salt tolerant varieties (Table 4). However, pH_2 reduction treated with 50% G.R. under non-salt tolerant traditional varieties was 9.0 meaning, thereby the reclaiming effect of tolerant varieties is equivalent to 25% G.R. Chhabra and Abrol (1977) have also reported the changes in ESP and improvement in physical properties of sodic soils with reduced dose of gypsum and growing of salt-tolerant varieties.

The infiltration rate after 3 years increased from 4.8 mm/day to 19.3 mm and 11.3 mm/ day at 50% and 25% G.R. levels, respectively. Acharya and Abrol (1991) have also reported considerable improvement in infiltration rate with the addition of gypsum in sodic soils. The organic carbon of the surface soil also increased due to addition of organic matter with continuous cropping.

Systems productivity and economics

The productivity of the system in tonnes of rice-equivalent yield was calculated on the basis of prevailing market price of rice and wheat during the years of experimentation. It was 7.96 t with application of gypsum @ 50% G.R. and growing of salt-tolerant varieties of rice 'CSR 13' and wheat 'KRL 19' and 7.28 t/ha with 25% G.R. and salt-tolerant varieties. However, system productivity at 50% G.R. with non-salt tolerant high-yielding varieties (7.20 t/ha) is at par (7.28 t/ha) with that of application of reduced dose of gypsum i.e. 25% G.R. and growing of salt-tolerant varieties. The cumulative input cost varied from 76,890 Rs/ha to 96,660 Rs/ha under treatments having different doses of gypsum (Table 5). The input cost of the treatment in which gypsum was applied @ 50% G.R. was higher about Rs 10,000 over the treatment where gypsum was applied @ 25% G.R. The cumulative net return after 3 years (61,440 Rs/ha) under the treatment 25% G.R. + salt-tolerant varieties was higher compared with other treatments because of net saving of about Rs 10,000 on account of gypsum during first year of experiment. Similarly, the combined effect of gypsum application @ 25% G.R. and growing of salt-tolerant varieties of rice and wheat gave the highest benefit: cost ratio (1.70) compared with that under 50% G.R. + salt tolerant (1.60) and non - salt-tolerant high-yielding varieties (1.49) because of saving of Rs 10,000/ha on account of reduced gypsum dose (25% G.R.) for reclaiming the sodic soils could not be compensated over 3 years by treating the soil with 50% G.R.

The application of reduced dose of gypsum (25% G.R.) and growing of salt- tolerant varieties of rice 'CSR 13' and wheat 'KRL 19' in sodic soils is highly cost effective and sustainable sodic soil reclamation technology for resource scarce situations.

Table 4. Effect of gypsum levels and varieties on soil properties at the end of 3 cycles of rice-wheat cropping system.

Gypsum levels (%G.R.)	Soil pH_2 (0-15cm depth)		ESP		Organic carbon (g/ kg)		Infiltration rate (mm/ day)	
	'KRL19'	'PBW343'	'KRL19'	'PBW343'	'KRL19'	'PBW343'	'KRL19'	'PBW343'
0	9.8	10.0	64	64	0.90	0.86	4.8	4.5
5	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	

Table 5. System's productivity and cost economics (x 10^3 Rs/ha) of rice-wheat cropping system as influenced by gypsum levels and varieties.

Treatment	System's productivity (t/ha)	Cumulative cost of cultivation	Cumulative net return	Benefit : Cost ratio
Control+ salt-tolerant varieties	0.90	76.89	-59.74	0.22
Control+ Non-salt tolerant traditional variety	0.55	76.89	-66.15	0.13
5% Gypsum requirement+ salt-tolerant varieties	4.67	82.88	19.55	1.23
5% Gypsum requirement + Non-salt tolerant traditional variety	3.75	82.88	-0.05	0.99
25% Gypsum requirement + salt-tolerant varieties	7.28	86.87	61.44	1.70
25% Gypsum requirement + Non-salt tolerant traditional variety	6.15	86.87	45.18	1.52
50% Gypsum requirement + Salt tolerant traditional variety	7.96	96.86	58.39	1.60
50% Gypsum requirement + Non-salt tolerant traditional variety	7.20	96.86	48.37	1.49

Salt-tolerant varieties, Non-salt tolerant traditional variety

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