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Effect of Variable Rates of Gypsum Application on Wheat Yield Under Rice-Wheat System

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Abstract: A field experiment was initiated during 2005-2006 to study the effect of gypsum application on rice and subsequent wheat crop. The direct, residual and cumulative effects of gypsum were also noticed under rice-wheat system. The gypsum was applied as 0, 1 and 2 t ha^{-1} with the basal dose of N, P_2O_5, K_2O as 120, 90 and 60 kg ha^{-1} to both crops. Rice variety IRRI6 and wheat variety Naseer 2000 were planted in Randomized Complete Block Design with three replications in a permanent layout. The soil samples were collected from both crops before earing to study P and K concentrations. The rice yield was significantly affected by gypsum application that ranged from 4807-5472 kg ha^{-1}. The highest rice yield was recorded by the application of 2.0 t gypsum ha^{-1} with an increase of 13.8% over control. Similarly all the yield components like number of panicles m^{-2}, panicle length, plant height and 1000 grain weight were also significantly affected by gypsum application. The wheat grain yield ranged from 2598 to 4304 kg ha^{-1}. The cumulative application of 1 and 2 t gypsum ha^{-1} increased the wheat yield by 25.25 and 65.66% over check, respectively. The direct and residual application of 2 t gypsum ha^{-1} gave an increase of 46.80 and 15.05% over the check, respectively. The application of gypsum significantly affected the P and K that ranged from 4.50-7.50 and 4.70-9.32 mg kg^{-1} P while 70-110 and 78-112 mg kg^{-1} K in rice and wheat, respectively.

Key words: Gypsum, rice, yield, rice-wheat system

INTRODUCTION

The sustainability of irrigated agriculture is confronted with the problems of waterlogging and salinity as productive lands have gone out of cultivation due to these problems. Saline and sodic soils occur naturally in arid and semi arid climatic conditions (Szabolcs, 1994). As water development brings more land into irrigation, the salinity problem expands (Kielen, 1996). Inadequate canal water supply has led farmers to use ground waters, more than 70% of which contain excess salts and high Residual Sodium Carbonate (RSC). This has resulted in crop yield reduction as well as soil degradation. Consequently, about 3.16 M ha of the canal commanded catchment area are salt affected; out of which 2.73 M ha are under cultivation and require corrective measures for its improvement for crop yield production.

The injurious effects of excessive salts are through reduced water uptake, nutritional imbalances and toxic effects of some of the ions. Crop yield can not be increased without proper judicious use and management of nutrients in soil. Most of our soils are calcarious with fairly high pH value thus rendering the unavailability of P and all micro nutrients except Mo. Any method that helps to normalize the soil pH will certainly improve the nutrients availability and crop productivity. In order to reclaim and bring the salt affected lands back to their full production levels, excessive salts need to be leached down below root zone with the application of good quality water.

Reclamation of salt affected soils involves a series of suitable techniques. It varies according to the nature and problem of soil, underground water quality and depth, quality and quantity of irrigation water, soil permeability, calcareousness and gypsum contents of soil, level of reclamation, crops to be grown, availability and economics of the reclaments. For reclamation of saline-sodic soils, gypsum is one of most commonly used amendments for reclamation of saline sodic/sodic soils, because of its low cost, easy availability and ease of handling (Ahmad and Salim, 2001). Naseem (2006) found that salt affected soils can efficiently and economically be reclaimed with the application of gypsum, compost, gypsum + compost, gypsum − press mud, gypsum + farm yard manure and gypsum + chiseling. These treatments significantly improved the soil parameters of Electrical

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Conductivity (EC), pH and Sodium Adsorption Ratio (SAR) and caused appreciable increase in yield of rice and wheat crops.

Competition among the agricultural and non-agricultural uses has decreased the sweet water availability for the former sector, which is expected to continue in future. As a consequence, brackish ground water high Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) is being pumped more and more to practice irrigated agriculture that might be a sustainability risk in the long run. Water quality parameters include EC for total soluble salts and SAR (high sodium with low Ca^{2+}+Mg^{2+}) and RSC (high CO_3^{-2}+HCO^{-3} or low Ca^{2+}+Mg^{2+}) reflect the sodicity hazards. Gypsum is also very helpful for sustainable use of low quality brackish irrigation waters for crop production. Niazi *et al.* (2003) conducted a series of experiments in rice- wheat system of Punjab and Sindh for developing management strategies for salt affected lands and brackish waters. They found that leaching of excess salts after gypsum application leads to adequate soil micronutrients supplies to support optimum crop growth. Gypsum is also very helpful for sustainable use of low quality brackish irrigation waters for crop production.

There are many reports that application of gypsum on normal soils has shown improved crop yields which may be possibly due to supplementation of soil with sulphur and calcium. Gypsum also acts as a source of plant nutrients i.e., Calcium and sulphur to the plants. It has 17% sulfate which is the most absorbable form of sulfur for plants. Calcium, which is supplied in gypsum, is essential for the biochemical mechanisms by which most plant nutrients are absorbed by roots. Without adequate calcium, uptake mechanisms would not function properly. Calcium also acts as a regulator of the balance of plant nutrients particularly the micro-nutrients such as Iron, Zinc, Manganese and Copper in plants. It regulates the uptake of non-essential trace elements. Calcium prevents excess uptake of many of them and once they are in the plant, calcium keeps them from having adverse effects when their levels get high. Calcium in liberal quantities helps to maintain a healthy balance of nutrients and non-nutrients within plants. It was also concluded that gypsum applied at lower rates may increase crop yields on normal soils due to supplementation of plant nutrients Hussain *et al.* (1992). Use of gypsum in combination with FYM was significantly better in improving the physical and chemical properties of soil and crops yield (Ramzan, 2001). Maximum grain (3605 kg ha^{-1}) and stalk (9922 kg ha^{-1}) yield of maize and wheat grain (3605 kg ha^{-1}) and stalk (12910 kg ha^{-1}) was recorded by application of recommended dose of NPK (120, 90 and 60 kg ha^{-1}) with 1000 kg gypsum ha^{-1} (Banaras *et al.*, 2003).

The broad objective of this study was to evaluate the residual, cumulative and direct application of gypsum on wheat yield in rice-wheat system.

MATERIALS AND METHODS

A field experiment was conducted during 2005-06 on rice to study the response of applied gypsum on rice and its residual/cumulative effect on wheat crop. The experiment was laid out at Arid Zone Research farm, D.I. Khan in Randomized Complete block design with five treatments replicated three times. The treatments comprised of No gypsum (control T_1), 2.0 t gypsum ha^{-1} to rice and Nil to wheat (T_2), Nil to rice and 2 t gypsum ha^{-1} to wheat (T_3), 2 t gypsum ha^{-1} to rice and wheat (cumulative T_4), 1.0 t gypsum ha^{-1} to rice and wheat (cumulative T_5). The basal dose of 120, 90 and 60 kg ha^{-1} of N, P_2O_5 and K_2O along with gypsum rates were applied in the form of urea, TSP, SOP and $CaSO_4$. All P, K, gypsum and half N was applied at sowing while the remaining half N was applied at 2nd irrigation at panicle initiation in rice. The variety sown for rice was IRRI 6 while Naseer 2000 variety was planted for wheat. The rice was planted during the Ist week of June while wheat was planted during the 2nd week of November. The treatment plot size of 2.40×6.00 m was kept for both crops as the wheat was planted in the same plots of rice. All the other cultural practices were followed uniformly throughout the growing period of each crop. A composite soil sample was collected before sowing of the rice and was analyzed for various physico-chemical characteristics (Table 1). The soil samples from individual treatments were collected after harvesting of rice and wheat to study some of the physico-chemical properties (Table 2). The yield components of both crops i.e. rice and wheat were recorded at proper time. At maturity two central rows (0.60 m×5.0 m^2) of each plot were hand harvested by sickle

Table 1: Physico-chemical properties of soil

Soil properties	Values
pH	8.00
Electrical conductivity dsm^{-1}	0.60
$CaCO_3$ Eq (%)	11.0
Organic matter (%)	0.76
Nitrogen (%)	0.038
Sod bicarbonate extractable P (mg kg^{-1})	4
Amm. acetate extractable K (mg kg^{-1})	85
Sand (%)	20
Silt (%)	44
Clay (%)	36
Textural class	Silty clay

Table 2: Effect of gypsum application on chemical properties of soil

	Gypsum (t ha^{-1})		Soil P (mg kg^{-1})		Soil K (mg kg^{-1})	
Treatments	Rice	Wheat	Rice	Wheat	Rice	Wheat
1	0	0	4.50[c]	4.70[c]	70	78[d]
2	2	0	6.00[b]	7.52[ab]	90	96[bc]
3	0	2	5.00[c]	6.25[bc]	85	89[c]
4	2	2	7.50[a]	9.32[a]	110	112[a]
5	1	1	6.00[b]	8.25[ab]	105	102[b]
LSD≤0.05			0.54	2.38	NS	8.15

Means followed by same letter(s) do not differ significantly at p≤0.05

and allowed to dry in the field. Seed was threshed manually for 1000 grain weight and grain yield of both rice and wheat. Data were analyzed using the analysis of variance (ANOVA) procedure and LSD (p≤0.05) values were calculated for comparisons among means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

P concentration in soil as affected by the application of gypsum: The gypsum application significantly affected the chemical properties of the soil under both rice and wheat crops (Table 2). The P content of the soil increased with gypsum application that ranged from 4.50-7.50 and 4.70-9.32 mg kg^{-1} after rice and wheat, respectively. The highest P contents were found with the application of 2 t gypsum ha^{-1} to rice and wheat, while lowest from check (T_1). Concentration of 8.25 mg kg^{-1} P was recorded with the application of 1 t gyp ha^{-1} to rice and wheat crop (T_5). The application of 2 t gypsum ha^{-1} (T_2) to only rice increased the P contents up to 7.52 while its direct application to wheat crop (T_3) increased the P contents up to 6.25 mg kg^{-1}. This all reflected that gypsum acts as plant nutrient source and supplies P for plant absorption.

K concentration in soil as affected by gypsum application: The gypsum application increased the K contents of the soil after rice, but the effect was non significant. It ranged from 70.0 to 110 mg kg^{-1} (Table 2). The gypsum application also significantly affected the K contents of the soil after wheat. The highest K concentration of 112 mg kg^{-1} was found in soil under wheat with the application of 2 t gypsum ha^{-1} to rice and wheat, while lowest from check (T_1). The second best concentration of 102 mg kg^{-1} K was recorded with the application of 1 t gypsum ha^{-1} to both rice and wheat crop (T_5). The application of 2.0 t gypsum ha^{-1} to only rice (T_2) increased the K contents up to 96 mg kg^{-1} and this level applied only to wheat crop (T_3) gave the value of 89 mg kg^{-1}. All this reflected that gypsum application of 2.0 t ha^{-1} increased K content significantly higher than 1 t gypsum ha^{-1} while lowest K contents in soil were found in both rice and wheat crop soils under check.

Rice grain yield and yield components as affected by gypsum application: The rice grain yield was significantly affected by gypsum application (Table 3) and ranged from 4807-5472 kg ha^{-1}. The highest yield i.e., 5472 and 5456 kg ha^{-1} was recorded from the application of 2.0 t gypsum ha^{-1}. This was followed by 5273 kg ha^{-1} yield recorded at 1.0 t gypsum ha^{-1}. The lowest yield of 4807 kg ha^{-1} was recorded from control. The plant height was significantly affected and ranged from 101.2 to 114.3 cm. The highest plants 114.3 and 112.0 cm was recorded by the application of 2.0 and 1.0 t ha^{-1} gypsum application, respectively but they were statistically different from each other. The lowest height of 101.2 and 107.8 cm was achieved from control plots. Gypsum rates also significantly affected the 1000 grain weight and ranged from 21.60-22.81 g. The maximum grain weight of 22.81 and 22.75 g was recorded from the application of 2.0 t gypsum ha^{-1}, followed by statistically similar 22.70 g grain weight at 1.0 t gypsum ha^{-1}. The panicle length ranged from 21.5-26.0 cm. The maximum panicle length of 26.0 and 25.4 cm were recorded by the application of 2.0 t gypsum ha^{-1} and was also non-significant with 25.5 cm panicle length recorded at 1.0 t gypsum ha^{-1}. The lowest 21.5 cm panicle length was obtained from control. The number of panicles m^{-2} was significantly affected over control and ranged from 329 to 395. The lowest number of panicles m^{-2} was achieved from control plots and highest was recorded at 2.0 and 1.0 t gypsum ha^{-1} but statistically non-significant. The highest grains yield of 13.8 and 13.5% was recorded from 2.0 t gypsum ha^{-1} followed by 9.7% yield increase over control at 1.0 t gypsum ha^{-1}. Shah *et al*. (2005) found that a fairly good crop of rice with a small profit margin could be raised in the first year itself, by applicating 20% of the gypsum requirements. Higher levels of gypsum proved economical only during subsequent years while application of gypsum beyond 80% of the requirement was of no avail. Soil pH declined with increase gypsum application. Chand *et al*. (2005) reported that application of gypsum with pressmud or with fulvic acid and zinc sulphate resulted in significantly higher rice yield in saline-sodic soil.

Wheat grain yield and yield components as affected by gypsum application: After the harvest of rice crop, wheat was planted on the same plots. The grain yield and yield components were significantly affected with the application of gypsum over check (Table 4). The wheat grain yield ranged from 2598-4304 kg ha^{-1}. The highest (4304 kg ha^{-1}) yield was achieved with the application of 2 t gypsum ha^{-1} both to rice and wheat (T_4) while lowest (2598 kg ha^{-1}) from check (T_1). The second highest yield

Table 3: Rice response to gypsum application under rice-wheat system

	Gypsum ($t\ ha^{-1}$)							
Treatments	Rice	Wheat	Grain yield ($kg\ ha^{-1}$)	Plant height (cm)	1000 grain weight (g)	Panicle length (cm)	Panicles (m^{-2})	Yield increase over control (%)
1	0	0	4807[c]	101.2[d]	21.60[c]	21.5[c]	329[b]	-
2	2	0	5472[a]	114.0[a]	22.75[a]	25.4[a]	395[a]	13.8
3	0	2	4863[c]	107.8[c]	22.36[b]	23.6[b]	361[c]	-
4	2	2	5456[a]	114.3[a]	22.81[a]	26.0[a]	394[a]	13.5
5	1	1	5273[b]	112.0[b]	22.70[a]	25.5[a]	390[a]	9.7
	LSD$\leq$0.05		117.3	1.317	0.32	1.083	11.22	-

Means followed by same letter(s) do not differ significantly at $p\leq0.05$

Table 4: Wheat response to gypsum application under rice-wheat system

	Gypsum ($t\ ha^{-1}$)							
Treatments	Rice	Wheat	Grain yield ($kg\ ha^{-1}$)	Plant height (cm)	1000 grain weight (g)	Spike length (cm)	Spike $(m)^{-2}$	Yield increase over control (%)
1	0	0	2598[e]	91.73[d]	36.49[e]	9.66[c]	204.3[c]	-
2	2	0	2989[d]	94.07[c]	39.43[d]	10.00[bc]	223.7[b]	15.05
3	0	2	3814[b]	95.80[ab]	41.29[b]	10.53[a]	257.0[a]	46.80
4	2	2	4304[a]	97.20[a]	42.23[a]	10.60[a]	266.7[a]	65.66
5	1	1	3254[c]	94.40[bc]	40.39[c]	10.20[ab]	237.3[b]	25.25
	LSD$\leq$0.05		75.0	1.47	0.53	0.41	15.4	-

Means followed by same letter(s) do not differ significantly at $p\leq0.05$

of wheat 3814 kg ha^{-1} was obtained by the application of 2 t gypsum ha^{-1} to wheat only (T_3), this yield was followed by the application of 1.0 t gypsum ha^{-1} added both to rice and wheat (T_5) and gave the wheat yield of 3254 kg ha^{-1} and it was higher than 2989 kg ha^{-1} which was achieved from the residual application of 2 t gypsum ha^{-1} (T_2).

Wheat plant height responded significantly to gypsum application and ranged from 91.73-97.20 cm. The highest plant was observed with the application of 2 t gypsum ha^{-1} added both to rice and wheat (T_4) while lowest from check (T_1). 1000 grain weight was also significantly affected with gypsum application over check. The maximum grain weight was also recorded with the application of 2 t gypsum ha^{-1} both to rice and wheat (T_4) while minimum from check. The spike length was also affected significantly and ranged from 9.66-10.60 cm. The highest length was achieved with the application of 2 t gypsum ha^{-1} to rice and wheat while lowest length was observed from check. The number of spikes m^{-2} were also significantly affected with gypsum application and ranged from 204.3-266.7. The highest number was observed with the application of 2.0 t gypsum ha^{-1} both to rice and wheat while lowest from check. The cumulative application of 1.0 and 2.0 t gypsum ha^{-1} increased the yield 25.25 and 65.66%, respectively. The direct application of 2.0 t gypsum ha^{-1} increased the yield by 46.8% while residual application of 2.0 t gypsum ha^{-1} increased the yield 15.05% over check. This all reflects that when 2.0 t gypsum ha^{-1} applied to rice and wheat gave the maximum yield of wheat sown after rice. Dhillan (2000) found that grain yield of rice and wheat increased by 0.4-0.8 t h^{-1} and in straw yield 0.4-1.1 t h^{-1} with the application of 0.8 t h^{-1} in a seleniferous soil.

CONCLUSION

Gypsum application significantly affected the rice yield and yield components. The application of 2.0 t gypsum ha^{-1} to rice gave an increase of 13.8% grain yield over check whereas application of 1.0 t gypsum ha^{-1} gave 9.7% increase over check. In case of wheat the cumulative application of 2.0 t gypsum ha^{-1} gave an increase of 65.66% over control and appeared more effective than the rest of the treatments.

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