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Sulphur Supply Enhances Wheat Growth and Yield on Saline-Sodic Soil

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Abstract. The effect of different S levels (0, 25, 50 and 75 kg S/ha) on growth and ionic concentration of wheat variety Inqlab-91 directly sown on saline-sodic soil (ECe=5.65 dS/m, pH=8.57 and SAR=17.38) was evaluated in a field experiment. Treatments were arranged using randomized complete block design (RCBD) with three replications. The crop was harvested at maturity, data on tillering, plant height, spike length, number of grains/spike, 1000- grain weight and yields (grain and straw) were recorded. Na, K, Ca and S concentrations in grain and straw were estimated using atomic absorption spectroscopy. Tillering, number of grains/spike, 1000- grain weight and grain yield significantly ($p \leq 0.05$) increased by enhancing the S application. Maximum wheat yield (4.66 t/ha) was recorded when S was applied at 75 kg/ha, which was 43% more than the control treatment. Maximum number of tillers/plant (161) and number of grains/spike (56) were recorded with sulphur applied at 75 kg/ha. Positive correlation ($r = 0.85$), ($r = 0.88$) between calcium, potassium and negative correlation ($r = -0.84$) between grain sodium content and wheat grain yield was recorded. It indicates that presence of significantly higher Ca and K contents of grain receiving S application might possibly help plants to attain more Ca and K and avoided sodium uptake to alleviate salinity/sodicity stress. Economical analysis showed that maximum value cost ratio (5.5:1) was achieved with the application of 25 kg S/ha.

Keywords: wheat growth, gypsum application, salt affected soil, sulphur levels

Introduction

Sulphur is a constituent of three S-containing amino acids (cistern, cystine and methionine), which are the building blocks of protein and a key ingredient in the formation of chlorophyll (Duke and Reisenaue, 1986). Without adequate S, crops cannot reach their full potential in terms of yield or protein content (Zhao *et al*., 1999). Wheat plants have a lower requirement for S than legumes and oilseed crops (Duke and Reisenaue, 1986). Sulphur is an essential element for growth and physiological functioning of plants (De Kok *et al*., 2002). Sulphur improves K/Na selectivity and increases the capability of calcium ion to decrease the injurious effect of sodium ions in plants (Badr *et al*., 2002; Wilson *et al*., 2000). Wheat requires a relatively high amount of supplemental S due to incompatibility of conditions with its period of most rapid growth during early spring, when the rate of S release from soil organic matter is quite slow (Johnson, 1999). Significant yield increases of winter wheat in response to S additions have been reported elsewhere (McGrath and Zhao, 1995; Randall and Wrigley, 1986). Elemental S and sulphate fertilizers increase 36% wheat grain yield (Riley *et al*., 2000). Under sulphur deficient conditions, crop growth and yield are declined, and the produce quality is adversely affected (Schonhof *et al*., 2007). Since the site under investigation is deficient in S, therefore, this study was designed to address the S issue.

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Materials and Methods

A field experiment was conducted to study the effect of S on growth and yield of wheat (Var. Inqlab-91) at Malik Farm, Farooqabad, and Sheikhupura during 2009-10. Sulphur treatments were assigned using randomized complete block design (RCBD) with three replications. The S treatments in this study were control, 25 kg S/ha, 50 kg S/ha and 75 kg S/ha. Gypsum as a source of S was selected for application. Different S levels were applied in designated treatments having plot size of 3.5x20 m. The recommended doses of N, P_2O_5 and K_2O at 100, 80 and 50 kg/ha, respectively were applied to all treatments. The crop was irrigated with tube well water throughout the growth period. All necessary plant protection measures were done whenever required. At maturity plants were harvested to record data on tillers/plant, spike length, number of grain/spike, 1000-grain weight and straw and grain yields/plant. Plant samples were oven dried at 60 °C to a constant weight and recorded dry matter yield. Grain and straw samples were ground using Wiley mill. Plant samples were then digested in perchloric-nitric diacid (2:1 1N) mixture (Rhoades, 1982) to estimate Na, K, Ca and Mg by atomic absorption spectroscopy. Available SO_4–S of soil samples was determined by the method as described by Bardesly and Lancaster (1960). The data thus obtained were analyzed using MSTATC and treatment means were separated using LSD. Tube well water applied to wheat crop had high residual sodium corbonates however, the soluble salts were present in permissible limit .The soil was saline sodic in nature. It was deficient in sulphur *i.e* less than 10 ppm (Ahmad *et al*., 1994). The physico-chemical properties of soil (Table 1) and the quality of tube well water applied to plants are given in Table 2, respectively.

Results and Discussion

Application of S to wheat crop grown on saline-sodic soil had positive influence on growth and yield of wheat (Table 3). The effect of S application on tillering, plant height, spike length, number of grain/spike, 1000 grain weight, straw and grain yield remained statistically significant. Maximum tillers (161) were recorded on plants received 75 kg S/ha followed by plants received 50 and 25 kg S/ha. Plant height and spike length were the highest in treatment receiving 25 kg S/ha. The highest 1000 grain weight (38 g) was recorded in treatment receiving 25 kg S/ha followed by 75 and 50 kg S/ha. High straw (10.26 tons/ha) and grain (4.66 tons/ha) yields were attained by plants treated with 75 kg S/ha which is 43% higher than control treatment. The S treatment receiving 50 kg S/ha registered second highest grain yield (3.91 tons/ha) which is 20% higher than control treatment followed by treatments receiving 25 kg S/ha producing 17% higher yield as compared to control treatment. Gupta *et al*. (2004) reported that S application significantly enhances wheat yield and yield components. This was possibly due to increased Ca and K in soil resulted in enhancing the availability of macro and micro-nutrients for healthy plant growth.

Table 1. Physico-chemical properties of soil at MK Farm, Farooqabad

Properties	Unit	Value
pH (1:1 H_2O)		08.57
ECe (1:1)	dS/m	05.65
SAR	(m mole$_c$ /L)$^{1/2}$	17.38
$CaCO_3$	%	07.00
OM	%	01.33
Sand	%	33.00
Silt	%	42.00
Clay	%	25.00
SO_4–S	mg/kg	07.26
Textural class (USDA)		Loam
pH (1:1 H_2O) after S application		08.10

Table 2. Quality of tubewell water applied to the crop

Quality	Unit	Value
pH	--	8.3
ECw	dS/m	1.6
RSC	meq/L	14.7
HCO_3^{-1}	meq/L	16.3

RSC = residual sodium carbonate.

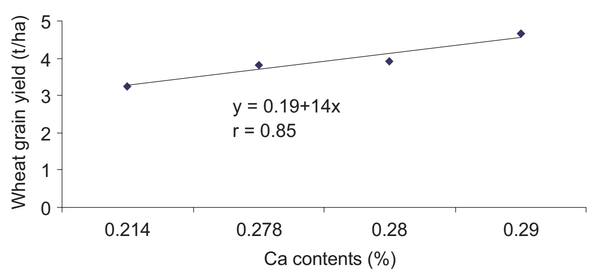

Fig. 1. Correlation between Ca content of grain and wheat grain yield.

Table 3. Effect of S on wheat growth and yield

Treatment	Tillers/ plant	Plant height (cm)	Spike length (cm)	Grains/ spike	1000 grain weight (g)	Straw yield (t/ha)	Grain yield (t/ha)
Control	64^{d}	71.7^{b}	6.2^{c}	34^{b}	32^{b}	4.26^{d}	3.26^{c}
25 kg S/ha	127^{c}	97.7^{a}	9.7^{a}	54^{a}	38^{a}	7.16^{c}	3.82^{b}
50 kg S/ha	147^{b}	97.6^{a}	8.5^{b}	54^{a}	36.6^{a}	8.7^{b}	3.91^{b}
75 kg S/ha	161^{a}	94.7^{a}	8.33^{b}	56^{a}	37.3^{a}	10.26^{a}	4.66^{a}
LSD	3.86	3.003	0.6892	5.508	2.746	0.8382	0.6125

a, b, c = indicate statistical significant differences among treatments.

Ionic concentration. The data presented in Table 4 indicates that the increasing concentration of S significantly increased K, Ca and Mg and decreased Na contents of grains. The highest content of calcium in grain was found in plants treated with 75 kg S/ha followed by plants treated with 50 kg S/ha. However, compared to the control treatment only, all the other treatments produced grains with significantly higher calcium content. The highest K content of grain was found in plants treated with 75 kg S/ha, followed by plants treated with 50 kg S/ha. Sulphur application ultimately resulted in better nutrient supply to wheat crop.

Figure 1 indicates significant positive correlation (r = 0.85) between calcium contents of grain and wheat grain yield. It indicates presence of significantly higher calcium content of grain, receiving S application help plants to attain more calcium and K to avoid sodium uptake which has been an added advantage to alleviate salinity/sodicity using crop residue incorporation apart

Table 4. Chemical analysis of grains for Ca, Na, K and Mg contents as influenced by S levels

S-Treatments	Ca %	Na%	K%	Mg%
T1= Control	0.214^{c}	0.217^{a}	0.415^{c}	0.134
T2= (25 kg S/ha)	0.278^{b}	0.208^{b}	0.434^{b}	0.151
T3= (50 kg S/ha)	0.280^{b}	0.185^{c}	0.463^{a}	0.142
T4= (75 kg S/ha)	0.290^{a}	0.183^{c}	0.469^{a}	0.139
LSD	0.006318	0.006318	0.006318	NS

a, b, c = indicate statistical significant differences among treatments; NS = non significant difference among treatments.

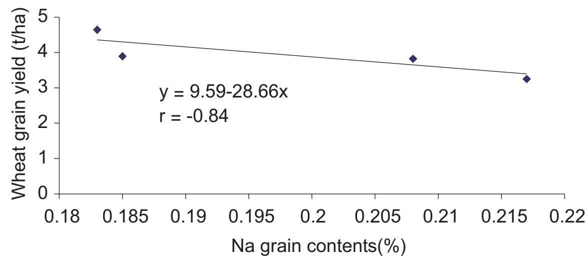

Fig. 2. Correlation between Na content of grain and wheat grain yield.

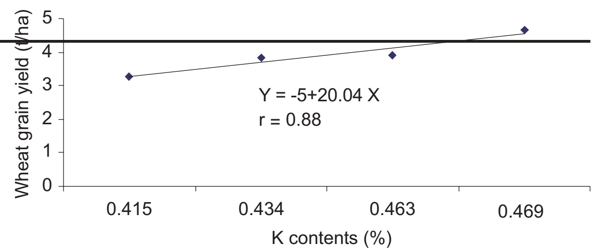

Fig. 3. Correlation between K content of grain and wheat grain yield.

Table 5. Economic analysis, partial budget analysis and dominance analysis of S on wheat crop yields

Dose		T1 Control	T2 25 kg S/ha	T3 50 kg S/ha	T4 75 kg S/ha
Input cost Rs.		0	2,500	5,000	7,500
Application Cost		-	-	-	-
Total cost that vary Rs.		0	2,500	5,000	7,500
Yield grain kg/ha		3260	3820	3910	4660
Adjusted yield (10% Low)		2934	3438	3519	4194
Output price Rs./kg		22	22	22	22
Straw yield kg/ha		4260	7160	8700	10260
Adjusted yield (10% Low)		3834	6444	7830	9234
Output price Rs./kg		2	2	2	2
Gross yield benefits Rs.		72216	88524	93078	110736
Net benefits Rs.		72216	86024	88078	103236
Dominance Analysis					
	TCV	0	2500	5000	7500
	NB	72216	86024	88078	103236
	VCR	-	5.5:1	3.2:1	4.1:1

TCV = total cost that vary; VCR = value cost ratio between values of additional crop produce to the additional money spent on S fertilizer.

from enhancing soil fertility and physical properties. Data in Fig. 2 indicates significant negative correlation ($r = -0.84$) indicating more sodium uptake where calcium and K uptake was the lowest in control treatment. Data in Fig. 3 shows significant positive correlation ($r = 0.88$) again indicating more potassium uptake as compared to control treatment. Chemical data indicates that application of sulphur combats salinity/sodicity by enhanced uptake of Ca and K.

Economical analysis. Economic viability of any intervention is must for adoption in field and is the basic theme of the research. All the agronomic practices and plant protection measures were same. The input cost in treatments receiving 25 kg S/ha, 50 kg S/ha and 75 kg S/ha was Rs. 2500, Rs.5000 and Rs.7500, respectively. Net benefits attained by treatments receiving 25 kg S/ha, 50 kg S/ha and 75 kg S/ha were Rs. 86024, 88078 and 103236, respectively, which were 19, 22 and 43% higher than control treatment (Table 5). The contribution of S towards wheat yield was investigated. Data in Table 5 indicates that treatments receiving 25 kg S/ha attained the highest value cost ratio (5.5:1) followed by application of 75 kg S/ha (4.1:1).

Conclusion

The present study envisages that S application not only enhances growth and yield of wheat on salt affected soil and it may increase the uptake of Ca and K ions and it reduces the uptake of toxic Na ions which helps to improve K/Na ratio.

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