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Effect of different levels of sulfur on the productivity of wheat in a saline sodic soil

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Abstract
A field experiment was carried out to evaluate the effect of different S levels (0, 25, 50 and 75 kg S ha^{-1}) on growth and ionic concentration of wheat variety (Inqlab-91) directly sown in a saline sodic soil (ECe=4.92 dS m^{-1}, pH=8.22 and SAR=16.15 dS m^{-1}) at Zaidi Farm, Sheikhupura during winter 2009. 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 $spike^{-1}$, 1000- grain weight, straw and wheat grain yields were recorded. Na, K, Ca and Mg concentration in grain and straw were estimated using atomic absorption spectroscopy. Tillering, number of grains $spike^{-1}$, 1000- grain weight, grain yield significantly ($p \leq 0.05$) increased by enhancing the rate of S application. Wheat grain yield was the maximum (4040 kg ha^{-1}) at the application of 50 kg S ha^{-1} and 26% more than control treatment. The maximum number of tillers / 5 plants (110), number of grains $spike^{-1}$ (63.6) and 1000 grain weight (47 g) were recorded with S application at 50 kg ha^{-1}. Positive correlations (r= 0.91) and (r=0.79) between calcium and potassium contents in grain and wheat grain yield. However negative correlation (-0.88) between Na content in grain and wheat grain yield was found. It indicates presence of significantly higher Ca and K contents in grains receiving S application help plants to attain more Ca and K to avoid sodium uptake which has been an added advantage to alleviate salinity/sodicity. However, economical analysis showed that maximum value cost ratio (3.52:1) was found where 25 kg ha^{-1} S was applied.

Keywords: Wheat, S application, saline-sodic soil

Introduction

Sulfur is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis. It is required in similar amount as that of Phosphorus (De Kok *et al*., 2002; Ali *et al.,* 2008). It is a building block 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). It is required for the synthesis of S containing amino acids such as cystine, cysteine and methionine. Their deficiency results in reduced plant height and stunted growth, reduced tillers, height, spikelets and delayed maturity. Sulfur deficient plants have also less resistance under stress conditions (Doberman and Fairhurst, 2000). Its fertilization helps enhancing the uptake of N, P, K and Zn in the plant. Due to its synergistic effect, the efficiency of these elements is enhanced which results in increased crop productivity. Application of S fertilizer is a feasible technique to suppress the uptake of undesired toxic elements (Na and Cl) because of the antagonistic relationship, thus its application is useful not only for increasing crop production and quality of the produce but also improves soil conditions for healthy crop growth (Tandon, 1991; Zhang *et al.,* 1999). Sulfur improves K/Na selectivity and increases the capability of calcium ion to decrease the injurious effects of sodium ions in plants (Wilson *et al.,* 2000; Badr *et al.,* 2002). Potassium availability in both agricultural and natural ecosystems frequently limits plant growth, development, and productivity (Leigh, 2001).

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 (Randall and Wrigley, 1986; McGrath and Zhao, 1995). Elemental S and sulphate fertilizers increased 36% wheat grain yield (Riley *et al.,* 2000). Sulfur application increased the grain S content at high N rather than low N treatment (Randall and Wrigley, 1986; Blake-Kalff *et al.,* 2000). Keeping inview the above mentioned facts, a study was conducted with the objective to investigate the effect of S application on growth and yield of wheat sown under saline-sodic soil.

Materials and Methods

A field experiment was conducted to study the effect of S on growth and yield of wheat crop (Var. Inqlab-91) at Zaidi Farm, Kakar Gill, Sheikhupura during Rabi season 2009-10. Treatments were assigned using randomized complete block design (RCBD) with three replications. The treatments of this study were T1=control, T2= 25 kg S ha^{-1},

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T3=50 kg S $ha^{-1}$and T4= 75 kg S ha^{-1}. Gypsum was used as a source of sulphur.

Different levels of S were applied in designated treatments having plot size 5x30 m. A recommended dose of N, P_2O_5 and K_2O at 100, 80 and 50 kg ha^{-1}, respectively were applied to all treatments. The crop was irrigated with tubewell water throughout the growth duration. All necessary plant protection measures were done whenever required. Data on tillers, spike length, number of grains $spike^{-1}$, 1000-grain weight, straw and wheat yield were recorded at the time of harvesting. Plant samples were oven dried at 60 ^oC to a constant weight and dry matter yield was recorded. Grain and straw samples were ground using Wiley mill. Ground plant samples were 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 test. Tubewell water (Table 2) applied to wheat crophad high RSC and soluble salts were present in permissible limit .The soil was saline sodic in nature. The physico-chemical soil analyses of the site are given in Table 1.

Table 1: Physico-chemical analysis of the soil at Zaidi farm

Parameter	Unit	Value
pH (1:1)		8.22
ECe (1:1)	d Sm^{-1}	4.92
SAR	$(m.mol_c\ L^{-1})^{1/2}$	16.15
SO_4-S	mg kg^{-1}	7.66
OM	%	1.30
Sand	%	39
Silt	%	30
Clay	%	31
Texture Class		Clay Loam

Table 2: Analysis of tubewell water

Parameter	Unit	Value
pH		7.9
ECw	dSm^{-1}	1.5
RSC	m eq L^{-1}	14.9
HCO_3	m eq L^{-1}	16.5

Results and Discussion

Different levels of S positively influenced wheat growth and yield (Table 3). Tillering, plant height, spike length, number of grain $spike^{-1}$, 1000 grain weight, straw and grain yield were statistically significant. The highest numbers of tillers (110) were recorded in treatment receiving 50 kg S ha^{-1} followed by treatments receiving 25 and 75 kg S ha^{-1}. Plant height was the highest in treatment receiving 25 kg S ha^{-1} and spike length was highest in the treatment receiving 50 kg S ha^{-1}. The highest 1000 grain weight (47 g), grain (4.04 tons ha^{-1}) and straw (5.8 ton ha^{-1}) yield were obtained with the application of 50 kg S ha^{-1} followed by 25 and 75 kg S ha^{-1}, which is 26% higher than control treatment. The treatments receiving 50 kg S ha^{-1} registered the highest grain yield followed by treatments receiving 75 kg S ha^{-1} producing 13% higher yield as compared to control treatment. Gupta *et al.*, (2004) reported that S application significantly enhanced wheat yield and yield components. This was the most probably due to increased Ca and K and decreased Na contents resulting in healthy environment for plant growth. Similar results have also been reported by Zhang *et al.* (1999), Prasad (2003) and Ali *et al.* (2008).

Ionic Concentration

The data in Table 4 indicated that concentration of Ca, Na, K, and Mg by grain was statistically significant with different levels of S at Zaidi farm and Kakar Gill. The highest content of calcium in grain was found in treatment receiving 75 and 50 kg S ha^{-1} followed by treatment having 25 kg S ha^{-1}. However, all the treatments produced grains having significantly higher calcium content may be due to $CaSO_4$ application as compared to control treatment only. Interestingly sodium content was the highest in control treatment as compared to all the other treatments indicating less sodium uptake where more calcium and potassium were present. The highest K content in grain was found in treatment receiving 75 kg S ha^{-1} followed by treatment receiving 50 kg S ha^{-1}. Sulfur application ultimately results in better nutrient supply to wheat crop.

Data in Figure 1 indicate significant positive correlation (r= 0.91) between calcium contents in grain and

Table 3: Effect of S on wheat yield and yield parameters

Treatment	Tillers/5 plants	Plant height (cm)	Spike length (cm)	Grain/ spike	1000 grain weight (g)	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})
Control	64 c	86.6 c	7.40 c	42.3 c	32 c	4.53 d	3.2 c
25 kg S ha^{-1}	96 b	105.0 a	9.50 b	56.3 b	43 b	5.03 c	3.60 b
50 kg S ha^{-1}	110 a	97.7 b	10.73 a	63.6 a	47 a	5.80 a	4.04 a
75 kg S ha^{-1}	96 b	99.96 ab	9.50 b	46.3 c	41 b	5.53 b	3.62 b
LSD	4.21	5.70	0.49	6.60	3.03	0.25	0.35

wheat grain yield. It indicates that presence of significantly higher calcium contents in grains receiving S application helps plants to attain more calcium and K to avoid sodium uptake which has been an added advantage to alleviate salinity/sodicity apart from enhancing soil fertility and physical properties. Data in Figure 2 indicate significant negative correlation (r = -0.88) indicating more sodium uptake where calcium and K uptake was the lowest in control treatment. Data in Figure 3 indicate significant positive correlation (r = 0.79) again indicating more potassium uptake as compared to control treatment. Chemical data indicates that application of sulphur combats salinity/ sodicity by enhanced uptake of calcium and K.

Table 4: Effect of S on Ca, Na, K and Mg contents in wheat grain at Zaidi farm, Kakar Gill

Treatment	Ca %	Na%	K%	Mg%
Control	0.034 b	0.166 a	0.544 c	0.136 a
25 Kg S ha^{-1}	0.040 ab	0.106 b	0.544 c	0.122 b
50 Kg S ha^{-1}	0.042 a	0.080 c	0.586 b	0.155 c
75 Kg S ha^{-1}	0.043 a	0.076 d	0.596a	0.106 d
LSD	0.007	0.006	0.005	0.006

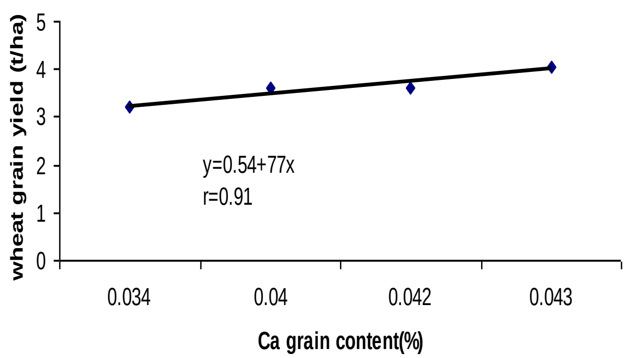

Figure 1: Correlation between Ca content of grain and wheat grain yield

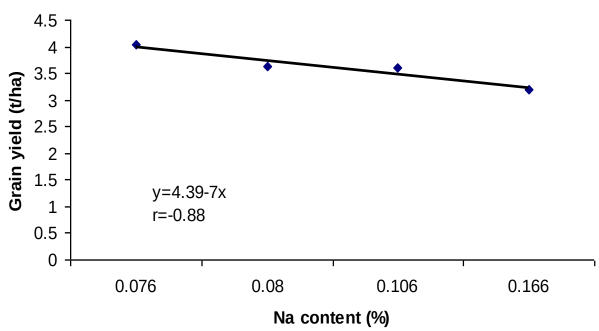

Figure 2: Correlation between Na content of grain and wheat grain yield

Economic 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^{-1}, 50 kg S $ha^{-1}$and 75 kg S ha^{-1} was Rs. 2500, Rs. 5000 and Rs. 7500, respectively. Net benefits attained by treatments receiving 25 kg S ha^{-1}, 50 kg S $ha^{-1}$and 75 kg S ha^{-1} were Rs. 8820, 10116 and 18916, respectively, which were 12.33, 14.14 and 26.45 percent higher than control treatment (Table 5). The contribution of S towards wheat yield was investigated. Data indicated that treatment receiving 25 kg S ha^{-1} attained the highest value cost ratio (3.52:1) as given below:

Dominance Analysis			
Treatment	**TCV (Total Cost That Vary)**	**NB**	***VCR**
T1	0	-	-
T2	2,500	8820	3.52:1
T3	5,000	10116	2.02:1
T4	7,500	18916	2.52:1

*Value Cost Ratio between values of additional crop produce to the additional money spent on S fertilizer; **NB:** Net benefit

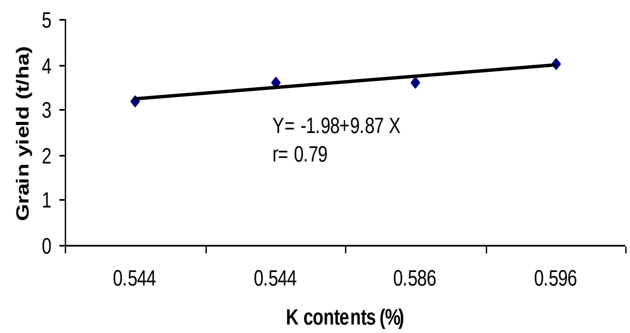

Figure 3: Correlation between K content of grain and wheat grain yield

Conclusion

Wheat yield was maximum (4.04 t ha^{-1}) at the application of 50 kg S ha^{-1} and 26% more than control treatment. However the maximum VCR 3.52:1 was found where sulfur was applied at 25 kg ha^{-1} to avoid sodium uptake which has been an added advantage to alleviate salinity/sodicity.

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Table 5: Economic analysis, partial budget analysis and dominance analysis of effect of S on wheat crop yields at Zaidi Farm

Dose		T1	T2	T3	T4
		Control	25	50	75
		kg S ha^{-1}			
Input cost Rs.		0	2,500	5,000	7,500
Application Cost Rs.					
Total Cost that Vary Rs.		0	2,500	5,000	7,500
Yield Grain	kg ha^{-1}	3200	3600	3620	4040
Yield Adjusted	(10% Low)	2880	3240	3258	3636
Output Price Rs./kg		22	22	22	22
Yield Straw	kg ha^{-1}	4530	5030	5530	5800
Yield Adjusted	(10% Low)	4077	4527	4977	5220
Output Price Rs./kg		2	2	2	2
Gross Field Benefits Rs		71514	80334	81630	90432
Net Benefits by sulphur application over NPK Rs.			8820	10116	18916

25kg ha^{-1} S=80334-71514=8820; 50kg ha^{-1} S=81630-71514=10116; 75 kg ha^{-1} S=90432-71514=18916

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