# CUMULATIVE EFFECT OF SULFUR AND CALCIUM ON WHEAT GROWTH AND YIELD UNDER SALINE-SODIC SOILS

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**ABSTRACT:- A field experiment was carried out to investigate the effect of three rates of gypsum on growth and ionic concentration of wheat variety (Saher) sown in saline-sodic soil (ECe=5.32 dS $m^{-1}$, pH=8.52 and SAR=18.87) at Soil Salinity Research Institute (SSRI) Farm, Pindi Bhattian during *rabi* 2009-10. 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 paddy yields were recorded. Potassium (K), Na, Ca, S and Mg concentrations in grain were estimated using atomic absorption spectroscopy. Tillering, grains $spike^{-1}$, 1000-grain weight and paddy yield significantly ($P \leq 0.05$) enhanced by increasing the rate of gypsum ($CaSO_4$). The maximum number of grains $spike^{-1}$ (60), 1000-grain weight (47 g) and grain yield (4.01 t $ha^{-1}$) were recorded with $CaSO_4$ application @ 150 kg $ha^{-1}$. Grain yield was 43% more than control treatment. Positive correlations (r= 0.96), (r=0.96) and (r=0.91) between $Ca^{2+}$, $K^+$, S and negative correlation r= (-0.99) between $Na^+$ contents in grain and wheat grain yield, respectively. It indicates presence of significantly higher $Ca^{2+}$, $K^+$ contents in grain receiving $CaSO_4$ help plants to attain more $Ca^{2+}$, $K^+$ and S to avoid $Na^+$ uptake.**

*Key Words: Wheat; Variety; Saline-Sodic Soil; Yield; Yield Components; Gypsum; Pakistan.*

## INTRODUCTION

According to the FAO/UNESCO soil map of the world, the total area of saline soils is 397 mha and that of sodic soils is 434 mha, which are not necessarily arable but cover all salt-affected lands at global level. Most of the salt-affected land lies in the arid and semi-arid environment. In Pakistan alone, out of 22 mha cultivated land, 6.28 mha is affected by salinity at variable level. Between 2 to 3 mha are categorized as wasteland due to high salinity and sodicity (Qureshi et al., 1993) but could be brought under cultivation by better cultivation, nutrient management techniques and better adopted crop varieties.

Management of the salt-affected soils requires a combination of agronomic practices depending on chemical amendments, nutrient supplementation, water quality and local conditions including drainage, climate, crop economics political / cultural environments and existing

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farming system. There is usually no single way to control salinity problems in irrigated agriculture. However, several practices can be combined into integrated system that functions satisfactorily (Mashali, 1995).

Sulfur (S) is one of the essential nutrients for plant growth. 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 Reisenauer, 1986) by improving plant growth due to increased supply of calcium ion ($Ca^{2+}$) and to decrease the damaging effects of salinity in plants (Badr et al., 2002). Calcium supply can increase both N use efficiency and hence plant growth as well as Na+ exclusion by plant roots (Aslam et al., 2001; Mahmood et al., 2009). Proportion of $Ca^{2+}$ becomes inadequate under saline sodic conditions and may result in reduced yields due mainly to ion imbalance (Aslam et al. 2001; Mahmood et al., 2009; 2010). Without adequate S and $Ca^{2+}$, crops cannot reach their full potential regarding yield or protein content (Zhao et al., 1999 and Blake-Kalff et al., 2000) Salt tolerant plants adopt many strategies that range from morpho-anatomical to physiological and biochemical in nature (Zhu, 2001). Sulfur and $Ca^{2+}$ improve K/Na selectivity and increases the action of $Ca^{2+}$ in reducing the injurious effects of $Na^{+}$ in plants (Wilson et al., 2000). Due to synergic effect of S and $Ca^{2+}$ in the presence of adequate N, P, K and Zn, their efficiency is enhanced which results in increased crop productivity. The improved S and $Ca^{2+}$ nutrition through gypsum application is an economical and practical treatment for suppressing the uptake of toxic elements (Na, Cl, Mg, Mo and Se) which are antagonistic to plant uptake of S and $Ca^{2+}$. Thus gypsum ($CaSO_4$) application is useful not only in increasing crop production and quality of produce but also in improving soil conditions for crop growth (Tandon, 1991).

Wheat requires a relatively high amount of supplemental S and $Ca^{2+}$ because of limitations in their supply to plants during most rapid growth period in early spring, when the rate of S and $Ca^{2+}$ release from soil organic matter is quite slow (Johnson, 1999). Significant yield increases of winter wheat in response to S and $Ca^{2+}$ additions have been reported elsewhere (McGrath and Zhao, 1995; Mahmood et al., 2010). Deficiency of S and $Ca^{2+}$ significantly affect the production and quality of wheat (McGrath, 2003; Gyori, 2005). Without adequate S and $Ca^{2+}$, crops can't reach their full potential regarding yield, quality or protein content; nor can they make efficient use of other applied nutrients (Sahota, 2006). The present study was therefore, conducted to investigate the effect of S and Ca (gypsum) on wheat growth and yield under saline-sodic soil conditions to enhance wheat yield from salt-affected lands.

## MATERIALS AND METHOD

A field experiment was conducted to study the cumulative effect of S and Ca on growth and yield of wheat (variety Saher) in naturally salt-affected soil (ECe = 5.32 dS $m^{-1}$; SAR = 18.87 mmole $L^{-1})^{½}$; pH = 8.52) at Soil Salinity Research Institute, Pindi Bhattian during *rabi* season 2009-10 (Table 1). Treatments were assigned using randomized complete block design (RCBD) with three replications. The treatments were 0, 100, 150 and 200 kg $CaSO_4$ $ha^{-1}$ (100 kg $CaSO_4$ = 23 kg Ca and 18 kg S).

Gypsum ($CaSO_4$) was applied in designated treatments having plot size 4m x 17m. A recommended basal dose of N, P and K @ 100, 80 and 50 kg $ha^{-1}$, respectively were applied to all the treatments. The crop was irrigated with tube well water (ECw = 1.7 dS $m^{-1}$; RSC = 15.2 mmol $L^{-1}$) throughout the growth duration (Table 1). All necessary plant protection measures were done whenever required. Data on tillers, spike length, grains $spike^{-1}$, 1000-grain weight, straw and grain yield were recorded at harvesting time. 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. Ground samples were digested in perchloric-nitric diacid (2:1 1N) mixture (Rhoades, 1982) to estimate K, Ca, S, Na, and Mg by atomic absorption spectrometry. The data thus collected were subjected to standard procedures of statistics and means were compared using LSD test at $P<0.05$ (Steel and Torrie, 1980).

**Table 1. Physico-chemical analysis of soil and tube-well water at SSRI Farm, Pindi Bhattian**

| Parameter | Soil value | Water value |
|---|---|---|
| pH (1:1) | 08.52 | 08.1 |
| ECe (1:1) (dS $m^{-1}$) | 05.32 | 01.7 |
| SAR (m.mole $L^{-1})^{1/2}$ | 18.87 | – |
| $CaCO_3$ (%) | 23.01 | – |
| Organic matter (%) | 00.52 | – |
| Ca+Mg (me $L^{-1}$) | 03.84 | – |
| $SO_4$-S (mg $kg^{-1}$) | 08.39 | – |
| RSC (m.mole $L^{-1}$) | – | 15.2 |
| $HCO_3$ (m eq $L^{-1}$) | – | 17.5 |
| Sand (%) | 63.00 | – |
| Silt (%) | 17.00 | – |
| Clay (%) | 20.00 | – |
| Texture Class | Sandy Loam | – |

## RESULTS AND DISCUSSION

Different levels of $CaSO_4$ (100, 150, 200 kg $ha^{-1}$) influenced positively wheat growth and yield (Table 2). Plant height, spike length, grains $spike^{-1}$, 1000-grain weight, straw and grain yield were considerably varied with $CaSO_4$ application and was the highest with receiving 150 kg $CaSO_4$ $ha^{-1}$ followed by 100 and 200 kg $CaSO_4$ $ha^{-1}$. The maximum produ-

**Table 2. Influence of Ca and S on growth and yield of wheat**

| $CaSO_4$ application (kg $ha^{-1}$) | Tillers | Plant height (cm) | Spike length (cm) | Grains $spike^{-1}$ | 1000-grain weight (g) | Straw yield (t $ha^{-1}$) | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| 0 | 63.66 | 64.73 c | 6.53 c | 46.73 c | 33.33 c | 04.767 d | 2.80 c |
| 100 | 68.00 | 77.03 b | 7.40 b | 55.83 b | 43.00 b | 08.500 c | 3.23 b |
| 150 | 66.67 | 86.20 a | 8.86 a | 60.86 a | 47.00 a | 10.700 a | 4.01 a |
| 200 | 69.00 | 82.93 ab | 8.76 a | 55.53 b | 46.33 ab | 09.967 b | 3.80 a |
| LSD | NS | 06.106 | 0.7738 | 04.073 | 03.477 | 00.477 | 0.322 |

*Means followed by same letter do not differ significantly at P ≤0.05* ction of straw (10.7 t $ha^{-1}$) and grain yield (4.01 t $ha^{-1}$), 43% higher than control treatment, was attained from application of 150 kg $CaSO_4$ $ha^{-1}$. These improvements in growth and yield contributing parameters and resultant increased straw and grain yields following $CaSO_4$ supplementation are presumably due to enhanced nutrient utilization because of better $Ca^{2+}/Na^{+}$ ratio reducing the adverse effect of $Na^{+}$. Consequently, $CaSO_4$ has thus reduced $Na^{+}$ toxicity and yield losses substantially. Further $Ca^{2+}$ and S have been reported to have a definite impact on plant establishment under saline sodic environment because of increased nutrients availability to the plants (Lahaye and Epstein, 1971, Aslam et al., 2001). Roots supplied with external $Ca^{2+}$ and S maintain their $K^{+}$ concentration and healthy crop stand due to increased nutrient use efficiency and hence plant growth as well as $Na^{+}$ exclusion of plant roots exposed to saline environment (Ali et al., 2003; Mahmood et al., 2009). Furthermore, $Ca^{2+}$ and S improve $K^{+}/Na^{+}$ selectivity of membranes and prevent the plant damage from toxic ions (Cramer et al., 1990; Kinraide, 1999; Aslam et al., 2000; Kaya et al., 2002).

The treatments receiving 200 kg $CaSO_4$ $ha^{-1}$ registered second highest grain yield (3.80 t $ha^{-1}$) which is 36% higher than control treatment followed by treatments receiving 100 kg $CaSO_4$ $ha^{-1}$ which resulted in a 15% higher yield as compared to control treatment. Gupta et al. (2004) reported that S application significantly enhanced wheat yield and yield components. This was most probably due to increased Ca and S contents in soil resulting in enhanced availability of macro and micronutrients due to synergic effect on plant growth. Similar results have also been reported by Zhang et al., (1999), Prasad (2003) and Ali et al., (2008).

## Ionic Concentration

The data indicated that concentration of S, K, Ca and Na in grain was statistically significant with different levels of $CaSO_4$ (Table 3). The highest contents of S (0.21 %) and $Ca^{2+}$ (0.20 %) in grain were found in treatment receiving 200 kg $CaSO_4$ $ha^{-1}$ followed by 150 kg $CaSO_4$ $ha^{-1}$ which were S (0.19 %) and $Ca^{2+}$ (0.18 %). However,

**Table 3. Ionic concentration (%) in wheat grain**

| $CaSO_4$ application (kg $ha^{-1}$) | S | Ca | K | Na | Mg |
|---|---|---|---|---|---|
| 0 | 0.118 d | 0.093 d | 0.385 c | 0.206 a | 0.086 |
| 100 | 0.157 c | 0.101 c | 0.435 b | 0.183 b | 0.087 |
| 150 | 0.188 b | 0.177 b | 0.453 ab | 0.162 c | 0.086 |
| 200 | 0.214 a | 0.204 a | 0.467 a | 0.151 d | 0.088 |
| LSD | 0.01782 | 0.006318 | 0.01998 | 0.006318 | NS |

*Means followed by same letter do not differ significantly at $P \leq 0.05$*

all the treatments produced grain having significantly higher S and $Ca^{2+}$ contents as compared to control treatment. Sodium contents were the highest in control treatment as compared to all the treatments receiving $CaSO_4$ reflecting lower $Na^+$ concentrations when more $Ca^{2+}$ and K were present. The highest K contents in grain were found in the treatment receiving 200 kg $CaSO_4$ $ha^{-1}$ followed by treatment receiving 150 kg $CaSO_4$ $ha^{-1}$. High $Na^+$ and low $K^+$ and $Ca^{2+}$ concentrations were recorded in grains harvested from control treatment while the effect of $CaSO_4$ application on Mg contents was statistically non-significant. This was probably due to selective $K^+$ transport compared to that of $Na^+$ in the presence of $Ca^{2+}$ supply resulting in less $Na^+$ and more $K^+$ contents in grain. External S and $Ca^{2+}$ supply in saline root medium presumably enhances $Na^+$ exclusion ability of plants to suppress $Na^+$ transport. Similar conclusions have been reported by Kupier (1984) and Ali et al. (2003) explaining that the root medium salinity interferes with the absorption and translocation of $K^+$ and $Ca^{2+}$ by plants. $CaSO_4$ application decreased $Na^+$ contents significantly and increased $Ca^{2+}$, S and $K^+$ concentrations in grain. This inference is supported by the results of Aslam et al. (2001) who have documented that at relatively higher concentration of $Ca^{2+}$, plants absorbed and translocated relatively more $K^+$ and less $Na^+$ than at lower concentration of $Ca^{2+}$, demonstrating the positive role of S and $Ca^{2+}$ in alleviating the harmful effects of salinity and sodicity.

Data indicated significant positive correlation (r=0.96) between $Ca^{2+}$ contents in grain and wheat grain yield (Figure 1). It indicates presence of significantly higher $Ca^{2+}$ contents in grain receiving $CaSO_4$ application help plants to attain more $Ca^{2+}$ and K to avoid $Na^+$ uptake which has an added advantage to alleviate salinity/sodicity and enhancing soil fertility. Data revealed significant negative correlation (r=-0.99) indicating antagonistic effect of $Na^+$ with $Ca^{2+}$ and K (Figure 2). Data also indicated significant positive correlation (r=0.96) again indicating synergic effect with K as compared to control treatment (Figure 3). Data indicated significant positive correlation

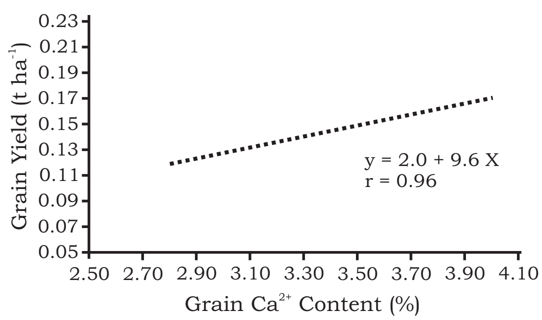


**Figure 1. Correlation between $Ca^{2+}$ content of grains and grain yield**

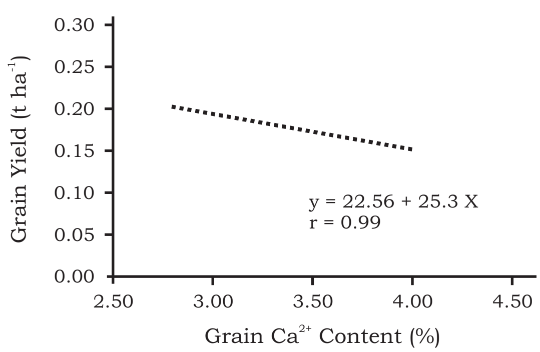


**Figure 2. Correlation between Na+ content of grains and grain yield**

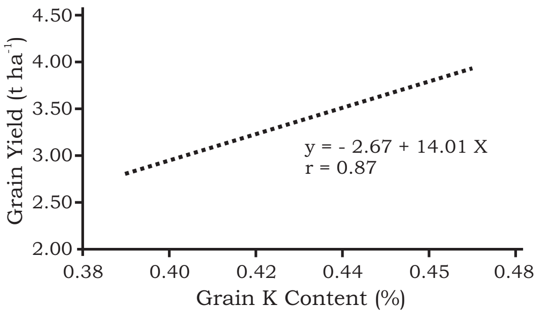


**Figure 3. Correlation between $K^+$ content of grains and grain yield**

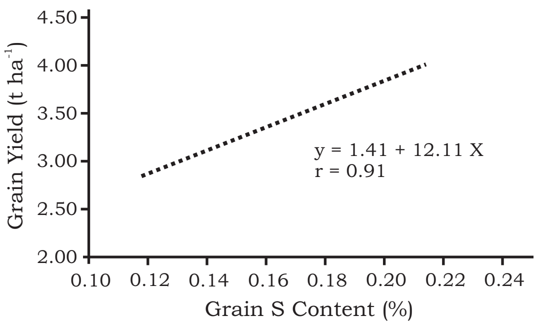


**Figure 4. Correlation between S content of grains and grain yield**

(r=0.91) between sulfur content in grain and wheat grain yield which in turn indicates presence of significantly higher S contents in grain receiving $CaSO_4$ application help plant to uptake more S content though their is deficiency of sulfur in saline sodic soil. Chemical data indicates that application of $CaSO_4$ combats salinity sodicity by increased concentration of $Ca^{2+}$, K and S.

This study therefore concluded that application of 150 kg $CaSO_4$ ha$^{-1}$ enhanced wheat yield reaching a maximum of (4.01 t ha$^{-1}$), 43% more than control treatment. Increased concentration of Ca and S in grain reduced the concentration of Na in grain. There was also a positive correlation with S levels in grain and wheat yields.

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