



Growth response, water relations and K/Na ratio in wheat under sodium and calcium interactions

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ABSTRACT: A study was conducted in the glass house to observe the role of K/Na ratio and moisture contents on the growth of wheat (*Triticum aestivum* L. cv. Lu-26) under NaCl stress. The plants were grown under hydroponic conditions at two salinity levels of 0 and 50 mM as NaCl. Calcium as CaSO₄. 2H₂O was applied at 3 and 6 mM to the pots of salinity. The plants were harvested after 30 days of growth. The treatments showed a highly significant ($p < 0.01$) effect on the growth and ionic relations. Fresh weight of shoot and root increased by 44 and 41 % respectively, with increased application of CaSO₄ from 3 to 6 mM in the saline medium. Dry mass was increased by 46% at 50 mM of NaCl with the application of 6 mM of CaSO₄. 2H₂O. Relative water content in the root decreased with the application of CaSO₄. 2H₂O in saline treatment as compared to non-saline treatment. The increased K/Na ratio had a pronounced effect on the increase of dry mass of shoot by 72% at 6 mM than 3 mM of CaSO₄. 2H₂O application in the saline medium. @JASEM

The change in the environmental conditions and enhanced stress on soil resources compel cultivators to engage deteriorating plant growth medium for the growth of highly demand food crops. Salinity has multi legend effects on the growth of a plant. High-salt stress is a major environmental factor that limits plant growth and productivity (Yordanov et al., 2003). Effects of salt stress have been examined in various salt-sensitive and -tolerant plants, including some crops (Cheesman, 1988). In Pakistan about 6.17 m ha land is salt affected, of which 45 % is cultivated land (Davidson, 2000; Qureshi and Barrett-Lennard, 1998). Wheat, besides a staple food crop, is an important cash crop of Pakistan. Wheat was cultivated on 8216.2 thousand hectares in Pakistan during the year 2003-04. For the successful growth of a crop it is necessary that within a plant organ moisture contents as well as ionic relations must be effective. In case of soil salinity the availability of water to plant is affected (Qureshi and Barrett-Lennard, 1998). With in a plant system hydraulic conditions are also changed as a function of external environment. Sodium is an important element of soil salinity/sodicity and it is undesirable for normal growth of a glycophyte system. It not only causes the water stress externally but also disturbs ionic relations of important plant nutrients. Calcium is an important nutrient required for building the cell wall, cell division, homeostasis and cell membrane integrity. Potassium is required for enzymatic reactions as well as for cell turgor pressure maintenance. Availability of Ca²⁺ in the external environment ameliorate NaCl stress (Zhong and

Lauchli, 1994). Elevated levels of external Ca²⁺, regulate and maintain K⁺ concentration in plants (Lauchli 1990). But application of excessive gypsum contributes to the availability of Ca²⁺ which may increase salinity in the root and shoot regions (Viswanathan et al., 2005). Its presence may be important for potassium ion and moisture contents of tissues. Enhanced level of calcium application in the root medium decreases its osmotic effects (Zaman et al., 2005). The response of wheat for growth may be variable as per status based on water contents and ions. Biosaline research is in progress in our institute with the main focus of determining means of growing wheat crop in salt affected areas of Pakistan (Ahmad et al., 2005; Iqbal et al., 2003; Zaman et al., 2005). This paper forms a part of a serial study conducted in the glass house to observe the role of K/Na ratio and moisture contents on the growth of wheat under NaCl stress.

MATERIALS AND METHODS

A hydroponic study was conducted under controlled conditions. Seeds of wheat (*Triticum aestivum* L. cv. Lu-26) were germinated in quartz sand supplied with distilled water. Twelve days old seedlings were foam-plugged in lids of plastic pots containing 2.5 L of continuously aerated Hoagland nutrient solution. The light intensity was 450 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Photoperiod was adjusted to 16 h light period and temperature was maintained at 30 ± 2 °C. The pH of the solution was adjusted to 6.0 with HCl or KOH and was regularly monitored. There were two salinity levels at 0 and 50

mM as NaCl. Calcium as $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ was applied at 3 and 6 mM to the pots of salinity. The salinity level (50 mM) was imposed 10 days after transplanting the seedlings by incremental addition of NaCl at 5 mM NaCl per day. The pots were arranged in complete randomized design in triplicate. The plants were harvested 30 days after sowing. The plants were rinsed with deionised water after recording fresh weight and were separated into shoot and root portions. These were dried at 65°C to constant weight. Dry weight of each sample was recorded and samples were ground to pass a 40-mesh Wiley Mill. Ground samples of root and shoot were digested in 2:1 perchloric-nitric di-acid mixture (Chapman and Pratt, 1961). Sodium, potassium and calcium ions in the digested material were determined by atomic absorption spectroscopy. The data were statistically analyzed according to CRD and treatment means were compared using LSD test (Gomez and Gomez, 1976).

RESULTS AND DISCUSSION

Salinity induced in the form of NaCl had a pronounced effect on wheat growth. There was a highly significant ($p < 0.01$) effect of the applied treatments on the growth parameters as well as ionic relations. Fresh weight of shoot decreased almost twice at 50 mM of NaCl along with the application of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ at 3 and 6 mM than gypsum treatments with out NaCl. Fresh weight of root was four times less than in treatment where NaCl was applied along with $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ at 3 mM. But at the same salinity level with $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ at 6 mM the biomass increased was twice than gypsum application with out NaCl. In the saline medium when the amount of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ was increased from 3 to 6 mM, fresh weight of shoot and root increased by 44 and 41%, respectively. Dry weight of shoot decreased almost twice at 50 mM of NaCl even the application of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ at 3 mM than the same treatment of gypsum with out NaCl. Dry weight increased by 46% at the same salinity level with the application of 6 mM of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.

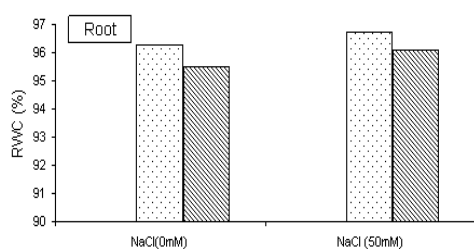


Table 1. Biomass production of wheat under NaCl and gypsum treatments.

| | Fresh Weight (g plant ⁻¹) | | | |
|-------------------------------------|---------------------------------------|-------------|------------|-------------|
| | Shoot | | Root | |
| | NaCl (0mM) | NaCl (50mM) | NaCl (0mM) | NaCl (50mM) |
| 3 | 6.42 a | 3.36 c | 4.24 a | 1.46 c |
| 6 | 2.89 d | 4.83 b | 1.36 d | 2.06 b |
| Dry Weight (g plant ⁻¹) | | | | |
| | mM | | | |
| 3 | 0.24 a | 0.11 d | 0.59 a | 0.35 b |
| 6 | 0.13 c | 0.19 b | 0.29 c | 0.05 d |

Means in columns for shoots and roots differ significantly at $p < 0.01$ for fresh weight and dry weight

In root dry weight was higher at both the levels of gypsum than the same treatments with NaCl. Along with $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ at 6 mM and NaCl shoot dry weight was 46% higher than the same level of gypsum treatment without NaCl. In the saline medium when the amount of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ was increased from 3 to 6 mM, dry weight of shoot increased by 73% and dry weight of root decreased 86% (Table 1). Relative water content in shoot and root was significantly affected decreasing both in the roots and shoots when $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ was increased from 3 to 6 mM. In the saline medium with the application of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ at 3 mM, relative water content of shoot was increased by 38% than the same treatment with out salinity. At 6 M of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ with salinity relative water content increased by 10 % than the same treatment with out salinity. In root the application of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ along with salinity decreased relative water content than the same treatments with out salinity (Figure 1). In non-saline medium when $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ was enhanced from 3 to 6 mM, relative water content decreased by 9%. In saline medium when $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ was enhanced from 3 to 6 mM, relative water content insignificantly decreased.

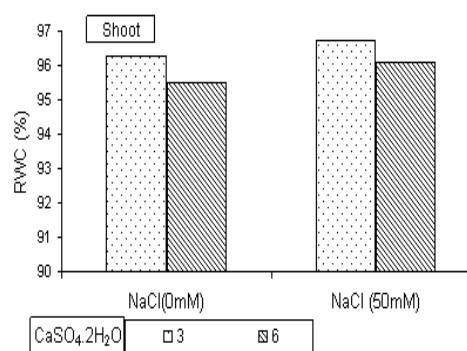


Fig 1. Relative water content in shoot and root of wheat under NaCl and gypsum treatments.



Root/shoot ratio decreased by 29 % by increasing $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ application from 3 to 6 mM in non-saline medium. Root/shoot ratio for dry weight declined in saline and non-saline medium when the level of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ was increased from 3 to 6 mM (Figure 2). At 3 mM of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ this ratio increased by 29% in saline medium than the non-saline medium. However, at 6 mM of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

the root-shoot ratio increased by 18% in saline medium than the non-saline medium. The increased K/Na ratio had a pronounced effect on the increase of dry weight of shoot by 72% at 6 mM than 3 mM of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ application in the saline medium. In root also K/Na ratio and dry weight were in synergistic relations. Dry weight increased by 43% with increasing $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ application (Figure 3).

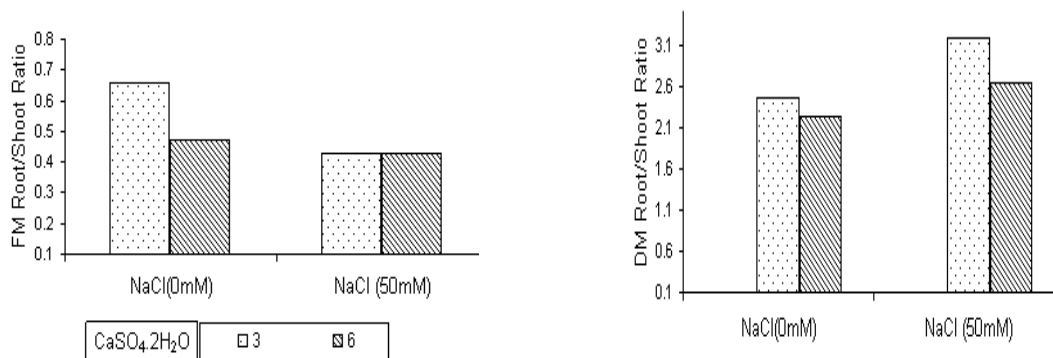


Fig 2. Root/shoot ratio of wheat under NaCl and gypsum treatments.

There was a highly significant ($p < 0.01$) effect of treatments on the growth and ionic relations of wheat. In the saline medium when $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ was increased from 3 to 6 mM, fresh weight of shoot and root increased by 44 and 41%, respectively. Accumulation of Na^+ in the shoot portion of the plant acted as an osmoticum. Plants grow in size by an increase in cell water content. Hiroshi and Boyer (1989) stated that if turgor does not fall, the growth inhibition must be attributed to other factors. In our

experiments the presence of sodium ion caused depletion of water contents in the root tissues. At 50 mM of NaCl with the application of 6 mM of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ dry mass was increased by 46 %. In root the application of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ along with salinity decreased relative water content as compared to non-saline treatments. The increased K/Na ratio had a pronounced effect on the increase of dry mass of shoot by 72% at 6 mM than 3 mM of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ application in the saline medium.

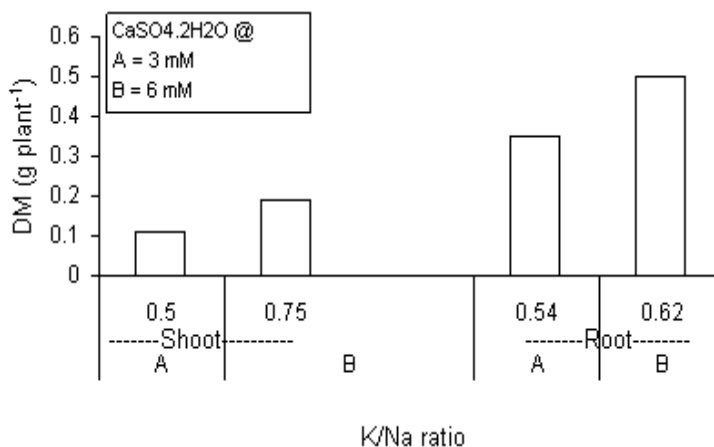


Figure 3. Root/shoot dry mass of wheat as affected by K/Na ratio.

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