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INFLUENCE OF CALCIUM ON WATER RELATION OF TWO CULTIVARS OF WHEAT UNDER SALT STRESS

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Abstract

The purpose of the present investigation was to study the effects of Ca^{2+} on water relation of two wheat cultivars (Akbar and Kanchan) under salt stress. The two wheat cultivars were grown in pots with 0 and 150 mM NaCl salinity. Calcium was applied in the form of gypsum in 0.12, 0.24 and 0.36g pot^{-1} (that is 20, 40 and 60 kg ha^{-1}) respectively. Salinity decreased RWC, WRC, exudation rate and ψ_{leaf}, while increased WSD and WUC. Application of increased levels of Ca improved the plant water status in both cultivars. The results obtained in the present study suggest that elevated Ca^{2+} increases salt tolerance by improving the plant water status.

Keywords: Calcium, Plant water relation, Salt stress, Wheat, Cultivar

Introduction

Salinity is an important environmental factor that can severely inhibit plant growth and agricultural productivity. Salt accumulation in irrigated soil is one of the main factors that diminish crop productivity, since most of the plants are not halophytic (Hoshida *et al*., 2000). Salinity disturbs the plant's water relations due to decreased availability of water from soil solution as a result of lowered osmotic potential (Munns, 2005), thus making it difficult for roots to extract water from their surrounding media (Mittler, 2002).

Crop improvement for saline conditions requires an understanding of the mechanisms enabling salt tolerance. Mechanisms of salt tolerance, not yet clear, can be to some extent explained by stress-adaptation effectors that mediate ion homeostasis, osmolyte biosynthesis, toxic radical scavenging, water transport and long distance response coordination (Neill *et al*., 2002). Chemical treatment and agronomical crop management practices have been tried to alleviate the salt stress, but the application of calcium to stressed plants attracted little attention. Supplementing the medium with Ca^{2+} alleviates growth inhibition by salt in plants (Imlay, 2003). Ca^{2+} sustains K^+ transport and K^+/Na^+ selectivity in Na^+ challenged plants. The interaction of Na^+ and Ca^{2+} on plant growth and ion relations is well established (Jaleel *et al*., 2007). The purpose of this study was to investigate the ameliorative effects of supplemental Ca^{2+} on water relation of two cultivars of wheat under saline condition which is associated with salt tolerance.

Materials and methods

Plant material

Two wheat cultivars, namely AKBAR (tolerant) and KANCHAN (susceptible) were selected as plant materials. The seeds were obtained from Bangladesh Agricultural Research Institute, Gazipur.

Analysis of soil

The soil for the experiment was collected from the botanical garden of Jahangirnagar university, Savar, Dhaka. The soil samples used in the pots were dried, powdered and mixed thoroughly. The physical and chemical properties of the soil were analyzed in the laboratory of Soil Resources Development Institute (SRDI).

Treatments

Saline water was prepared artificially by dissolving calculated amount of commercially available salt (NaCl) with tap water to make 150 mM NaCl solution. Tap water was used as control.

Levels of calcium

Three levels of calcium were applied in the form of Gypsum.

Low (Ca1) = 20 kg ha^{-1} (0.12g pot^{-1}), which is 50% of the recommended dose.

Optimum (Ca2) = 40 kg ha^{-1} (0.24g pot^{-1}), which is 100% of the recommended does.

High (Ca3) = 60 kg ha^{-1} (0.36g pot^{-1}), which is 150% of the recommended dose.

Nitrogen, potassium and phosphorus were applied in the form of urea, MP and TSP as their recommended does, 180, 110, 140 kg ha^{-1}, (1.08g pot^{-1}, 0.66 pot^{-1} and 0.84g pot^{-1}), respectively.

Methods of cultivation

Each pot was filled up with 12kg air-dried soil. The respective amount of nutrients was incorporated with the soil before seed sowing. The compost was $1/4^{th}$ of the soil by volume. The pots were kept under natural sunshine. The seeds were surface sterilized by soaking the seeds with 0.1% sodium hypochloride for three minutes followed by washing 7 to 8 times with tap water and three times with distilled water. Seeds of uniform size were directly sown on 12 November, 2006. Tap water was applied in all pots up to the emergence of seedling. After seedling establishment tap water in control pots and 12.5mM NaCl solution were applied in salt treatment. When the first leaf appeared i.e. ten days after emergence (DAE) actual amount of NaCl solutions were applied. Seedling in control group was irrigated with tap water.

Measurement of plant water status

Leaf (lamina) of same size and age of five seedlings from each treatment was collected and fresh weight of the leaf was taken immediately. The leaf was kept immersed in distilled water for 24 hour at room temperature in the dark. The turgid weight of the leaves was then measured. Afterwards the leaves were oven-dried at 80˚C for 72 hour in order to take dry weight. The fresh, turgid and dry weights of the leaves were used to determine the following parameters (Sangakkara *et al*., 1996):

$$\text{Relative Water Content (RWC)} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

Water Saturation Deficit (WSD) = 100 - RWC

$$\text{Water Retention Capacity (WRC)} = \frac{\text{Turgid weight}}{\text{Dry weight}}$$

$$\text{Water Uptake Capacity (WUC)} = \frac{\text{Turgid weight - Fresh weight}}{\text{Dry weight}}$$

Measurement of Exudation rate

Exudation rate was measured at 5 cm above from the base of the stem. At first, dry cotton was weighed. A slanting cut on stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exudation of sap was collected from the stem for 1 hour at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was measured by deducting cotton weight from the sap containing cotton weight and expressed in mg per hour as follows:

$$\text{Exudation rate} = \frac{(\text{Weight of cotton} + \text{sap}) - \text{Weight of cotton}}{\text{Time (h)}}$$

Measurement of Leaf water potential

Leaf water potential was measured at 6AM by pressure-bomb technique (Tyree and Hammel, 1972).

Results

Relative water content**:** Salinity decreased RWC. RWC increased with the application of Ca from Ca_1 to Ca_3 levels both under control and saline conditions of the two varieties of wheat (Table 1).

Water saturation deficit**:** Salinity increased WSD at all levels of Ca (Ca_1, Ca_2 and Ca_3) compared to those of corresponding levels of Ca under control condition. The WSD showed a decreasing tendency due to application of higher level of Ca (Table 1).

Water retention capacity**:** Salinity reduced WRC significantly compared to that of control at all levels of calcium. However, application of Ca increased WRC both in control and salt treated plants of the two varieties of wheat (Table 1).

Water uptake capacity**:** Salinity increased WUC compared to that of control. Application of calcium decreased WUC in both control and saline condition (Table 1).

Exudation rate and leaf water potential**:** Salinity decreased exudation rate drastically. Application of increased level of Ca from Ca_1 to Ca_3 increased the exudation rate significantly both under control and saline condition (Table 2). Leaf water potential (ψ_{leaf}) decreased with the salinity. The ψ_{leaf} showed an increasing tendency with the increasing levels of Ca application (Table 2).

Discussion

The relative water content (RWC) signifies the water contents of plants. The relative water content was decreased by salinity (Table 1). Application of increased level of Ca from Ca_1 to Ca_3 increased the relative water content significantly both under control and saline condition (Table 1). Reduction in RWC due to salinity was reported in different crops by many workers (Ghoulam *et al.*, 2002 in sugar beet; Sayed and Gadallah, 2002 in sunflower). It is well known that salinity decreases soil water potential and thus reduces the water uptake by plant that reflect in the lower RWC. The results of this study imply that application of Ca exerted beneficial effect of water uptake which was reflected with the higher RWC. Similar effect was reported by Francisco *et al*. (2004) in pepper plant.

Water saturation deficit (WSD) showed an inverse trend of RWC. Water saturation deficit indicates the degree of water deficit in plants. As expected salinity increased WSD at all levels of Ca (Ca_1, Ca_2 and Ca_3) compared to those of corresponding levels of Ca under control condition. The WSD showed a decreasing tendency due to application of higher level of Ca (Table 1). Under saline condition plants suffered from water deficit especially at high salt concentration (Orcutt and Nilsen, 2000), though information on Ca-induced change in WSD under saline condition is scarce. The result of the present study agrees well with that of Cheeseman (1988).

Water retention capacity (WRC) illustrates the capacity of plant cell to retain water. Water retention capacity is determined by cell structure. Plant grown under a high moisture regime maintains a higher ratio that could be due to the lower destruction of plant tissues by moisture deficit (Sangakkara *et al.,* 1996). Islam (2001b) showed in bushbean that plants grown under a high soil moisture regime had a higher ratio than that of the plants grown under mild stress and severe stress conditions. Salinity reduced the WRC significantly compared to that of control at all levels of calcium. However, application of Ca increased this ratio both in control and salt treated plants of the two cultivars of wheat (Table 1).Under saline condition the highest ratio was observed at the highest level of calcium indicating that the capacity of plant to absorb moisture increased with the increased level of calcium. Similar result was reported by Cramer *et al*. (1989) in barley.

The water uptake capacity (WUC) quantifies the ability of a plant to absorb water per unit dry weight in relation to turgid weight. A higher water uptake capacity under saline condition means a plant is subjected to water stress at a greater degree, because the plant would absorb more water to reach turgidity than a plant under control condition (Islam, 2001b). Salinity resulted in an increase in the water uptake capacity compared to that of control. Application of calcium decreased WUC in both control and saline condition. Therefore, calcium exerted a positive role to maintain better water relation under both control and saline condition. Similar effect was reported by Grieve and Fujiyama (1987) in rice and Francisco *et al*. (2004) in pepper plant.

Under normal condition exudation rate is higher than that of under stress condition. Exudation can thus be used as an indicator to measure the severity of stress. Salt stress decreased exudation rate drastically. Application of increased level of Ca from Ca_1 to Ca_3 increased the exudation rate significantly both under control and saline condition (Table 2). The highest exudation rate (264.301 mg/h in Akbar and 248.062 mg/h in Kanchan) was observed under control condition applied with Ca_3 and the lowest (83.521 mg/h in Akbar and 68.430 mg/h in Kanchan) was under saline conditions with Ca_1. Therefore, greater amount of Ca had a positive role on the maintenance of water relation of the two varieties of wheat under saline condition. A significant positive correlation (r^2=0.9647 in Akbar and r^2=0.9983 in Kanchan at control and r^2=0.9603 in Akbar and r^2=0.9967 in Kanchan at 150 mM; significant at 1% level) between levels of Ca and exudation rate was noticed (Fig.1 and 2). The lower exudation due to salinity indicated that the plant was subjected to water stress (Sangakkara *et al.,* 1996). Exudation rates directly related with the flow of transpiration stream. Increased exudation rate means a plant can absorb more water from the soil solution than a plant with lower exudation rate. However, it is not clear from this study how higher levels of Ca increased the exudation rate. Further study is needed to elucidate the mechanisms of Ca induced enhancement of exudation in wheat.

Table 1: Effect of salinity and calcium levels on relative water content, water saturation deficit, water retention capacity and water uptake capacity of cv. Akbar and Kanchan

Salinity levels (mM)	Calcium levels (kg/ha)	Relative water content (%)		Water saturation deficit (%)		Water retention capacity (TW/DW)		Water uptake capacity	
		Akbar	Kanchan	Akbar	Kanchan	Akbar	Kanchan	Akbar	Kanchan
0	20 40 60	75.15 77.30 79.48	78.04 79.08 80.02	14.78 13.54 12.18	14.98 13.88 12.50	4.20 4.98 5.50	4.85 5.10 5.75	0.50 0.36 0.30	0.56 0.52 0.36
150	20 40 60	50.44 52.72 59.22	42.58 44.20 50.05	35.00 25.45 16.32	40.02 28.08 18.12	3.60 4.06 4.98	3.15 4.06 4.40	1.66 1.38 1.08	2.02 1.84 1.18
LSD (5%) CV (%)	- -	1.78 19.90	1.36 29.70	0.83 45.60	1.82 50.60	0.92 15.60	0.56 19.80	0.07 65.30	0.05 66.40

Table 2: Effect of salinity and calcium levels on exudation rate and leaf water potential of var. Akbar and Kanchan

Salinity levels (mM)	Calcium levels (kg/ha)	Exudation rate (mg/h)		Leaf water potential (MPa)	
		Akbar	Kanchan	Akbar	Kanchan
0	20 40 60	232.500 243.135 264.301	224.062 235.203 248.062	-0.564 -0.546 -0.504	-0.520 -0.500 -0.458
150	20 40 60	83.521 89.527 102.063	68.430 79.520 88.605	-0.815 -0.725 -.0720	-0.798 -0.710 -0.638
LSD (5%) CV (%)	- -	10.19 50.70	8.23 55.00	0.042 -47.80	0.051 -22.10

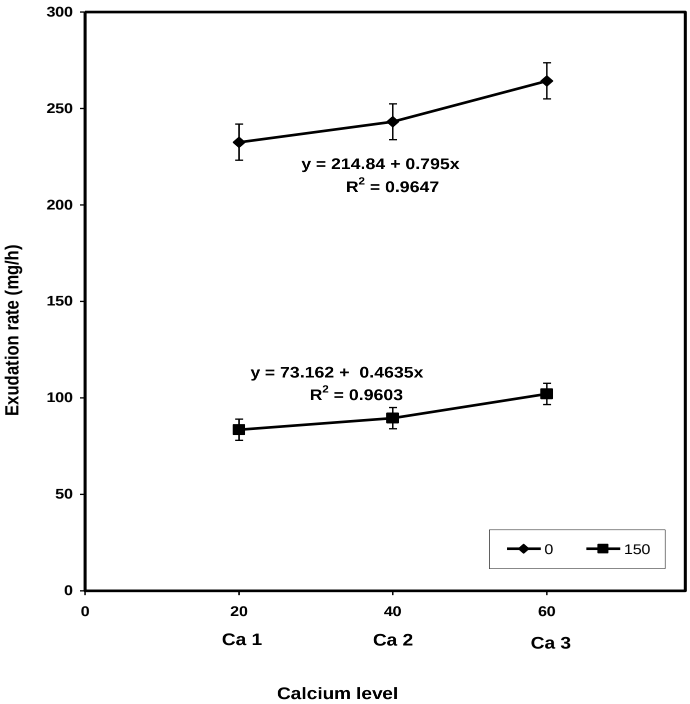

Fig. 1 Relationship between calcium levels and exudation rate of Akbar under saline conditions. Bars indicate ± SE .

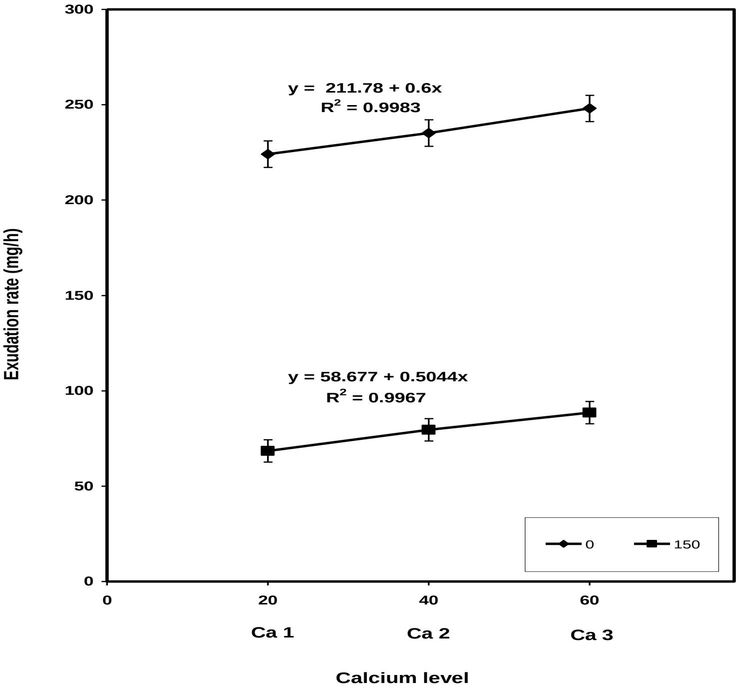

Fig. 2 Relationship between calcium levels and exudation rate of Kanchan under saline conditions. Bars indicate ± SE .

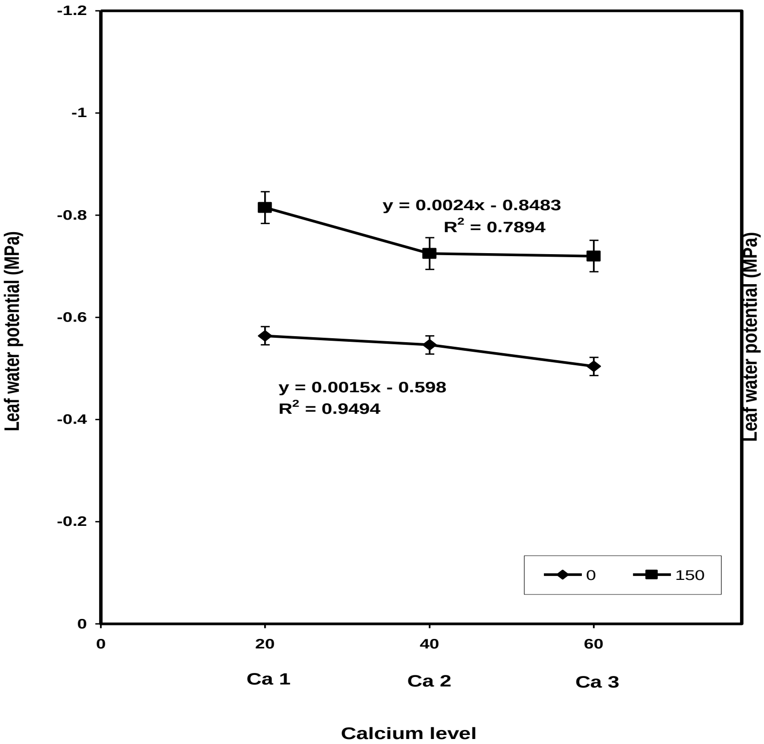

Fig. 3 Relationship between calcium levels and leaf water potential of Akbar under saline conditions. Bars indicate ± SE.

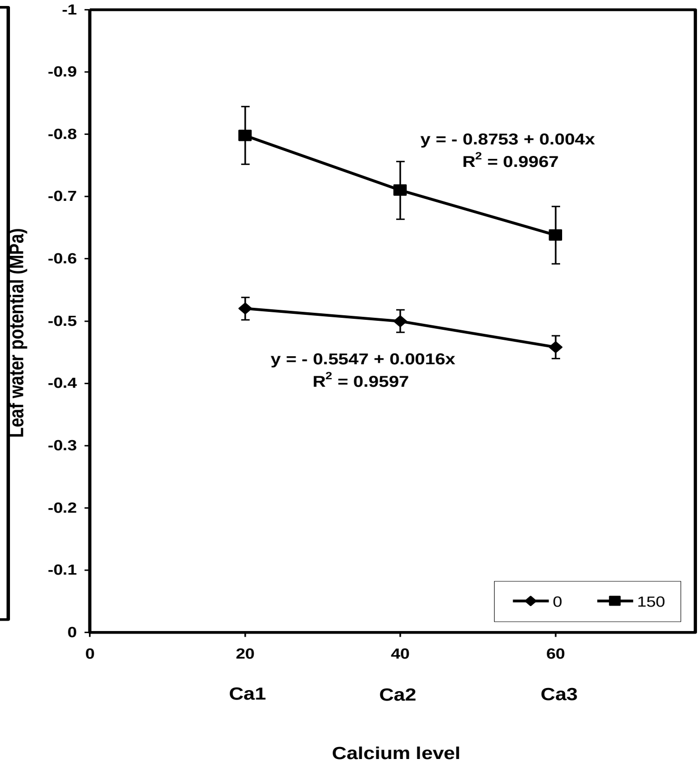

Fig. 4 Relationship between calcium levels and leaf water potential of Kanchan under saline conditions. Bars indicate ± SE.

Leaf water potential (ψ_{leaf}) decreased with the salinity (Table 2). The ψ_{leaf} showed an increasing tendency with the increasing levels of Ca application. The highest ψleaf (-0.504 in Akbar and -0.458 MPa in Kanchan) was recorded from Ca3 applied under control conditions and the lowest (-0.815 in Akbar and -0.798 MPa in Kanchan)) was from Ca1 under saline conditions. A positive correlation ($r2=0.9494$ in Akbar and $r2=0.9597$ in Kanchan at control and $r2=0.7894$ in Akbar and $r2=0.9967$ in Kanchan at 150 mM; significant at 1% level) between ψleaf and levels of Ca was found (Fig.3 and 4). The decreased ψleaf due to salinity was reported by many workers for different crops (Nandwal et al., 2000; Carvajal et al., 1999). Kramer (1988) found that with the increase in Ca, ψleaf increased under saline condition in barley. Plant synthesizes different metabolites across the tonoplast to maintain turgor. However, the plants need to spend substantial energy to maintain turgor under water deficit conditions (Munns and Termaat, 1986). Higher ψleaf in optimal and high Ca salinized plant might suggest a mechanism of osmotic adjustment or an increase in cell wall elasticity.

Conclusion

From these results, it can be concluded that the addition of calcium to salt (NaCl) stressed wheat has a significant role in partial alleviation of salinity stress by improving the plant water status.

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