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THE ROLE OF POTASSIUM NITRATE IN ALEVIATING DETERIMENTAL EFFECTS OF SALT STRESS OF SOYBEAN ROOTS *IN VITRO*

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ABSTRACT

The effect of different concentrations of saline solution under three levels of potassium nitrate of MS medium on growth and development of soybean roots *in vitro* was studied. This study included also the morphological responses of soybean roots to the previous treatments in relation to growth, succulence, some biochemical and mineral composition. Salt tolerance was evaluated by the capability of root to resume growth under salt stress. At higher rates of saline solution under nutritional levels of potassium nitrate, root growth and Ca^{2+}, K^{+} uptake were found to be more restricted than with lower ones. The results indicate that the decrease in fresh and dry weights of soybean roots were associated with the high level of salinity. Saline solution at 2000 ppm gave the best morphological parameters, proline and free amino acids contents. Nitrogen and crude protein % were decreased by raising saline solution concentration up to 4000 ppm under the highest level of potassium nitrate but opposite trend was found with 6000 and 8000 ppm of saline solution. The Ca^{+2}/Na^{+} and K^{+}/Na^{+} ratios of soybean roots were higher in the control than those of saline treatments. A significant increase in proline concentrations was observed by saline solution at 4000 ppm untill 8000 ppm. In general, the previous changes could be considered as a good parameter for salt tolerance plant.

Key Words: Soybean, *Glycine max*, Salt tolerance, Saline solution, Potassium nitrate, Root growth

INTRODUCTION

Soybean (*Glycine max* L.) is one of the world's main sources of edible vegetable oils and high-protein livestock feed (Greenway and Munns, 1980; Läuchli, 1984). It is generally considered as one of the salt-sensitive crops. Salinity is an environmental stress that limits growth and development in plants. The response of plants to the excess of NaCl is complex and involves changes in their morphology, physiology and metabolism (Hare *et al.*, 1996).

Achilea and Barak (1999) mentioned that potassium nitrate is an ideal fertilizer for a safe crop nutrition regime under saline conditions. The ratio of the two nutrients is similar to the optimal ratio found in many crops. Furthermore, considering the positive contribution of NO_3^- and K^+ against the deleterious effect of Cl^- and Na^+, respectively, KNO_3 and its derivatives should be the basis for sustainable crop nutrition for N and K.

Thus distribution of K^+ and Na^+ between vacuole and cytoplasm appears to be crucial for salt tolerance (Jeschke, 1979). Improvement of growth in the saline substrate could be achieved by doubling the nutrient concentration in the solution (Amzallag *et al.*, 1992). Adverse effects of soil salinity can also be reduced by promoting vigorous growth through good management and adequate fertility (Blaylock, 1994). Alleviation of salt stresses can be achieved by different irrigation, fertilization, soil aeration, leaching practices or through use of nutrients, hormones, chemical and physical treatments and biological methods (El-Saidi, 1997).

Crowley *et al.* (1999) suggested that maintenance of high potassium and calcium in the root zone might help to offset the effect of salinity. Cakmak (2005) suggested that the improvement of K^+ nutritional status of plants might be of great importance for the survival of crop plants under environmental stress conditions. Accumulation of Na^+ and impairment of K^+ nutrition is a major characteristic of salt-stressed plants. Therefore, K^+/Na^+ ratio in plants is considered a useful guide to assessing salt tolerance (Santa-Maria and Epstein, 2001). However, by increasing the N supply to the soil the effect of salinity was alleviated. Under salinization, reduced uptake of N by crops appears to be due to more intake of Na^+ as well as Cl^- by the roots. Increased levels of Na^+ in the plant tissues cause nutrient imbalance and displace Ca^{2+} from exchange sites on the

membranes and cell walls. Chloride presents more than 100 mM concentration in the saline medium inhibited NO_3^- uptake possibly due to increased accumulation of Cl^- in the roots.

Plant roots provide an attractive experimental system for investigating salinity effects on growth and other parameters for the following reasons: (a) they have a definable growing region in the tip and a separate nongrowing region consisting of mature, elongated cells, some distance behind the tip (Ishikawa and Evans, 1995), and (b) root cells can be directly exposed to different NaCl concentrations by changing the root medium. In addition, the first part in plant encounter salinity stress is the root system. So from the previous reasons the present investigation was chosen the root rather than other parts of plant. Furthermore, the root response under different salinity levels was examined by elevating macronutrients and iron in medium.

The objectives of the present investigation were: (1) minimize the harmful effect of salinity, (2) to evaluate the mechanism of salt tolerance in root system.

MATERIALS AND METHODS

This experiment was conducted to study the effect of different concentrations of saline solution under three levels of potassium nitrate of MS medium on growth and development of soybean roots *in vitro*. Saline solution contains [3 NaCl + ½ (6 $MgCl_2$ + 1 $CaCl_2$ + 1 KCl)] was used according to Taiz and Zeiger (1998).

1. Plant Material

Soybean seeds (*Glycine max* L.) cv. Giza 111 obtained from Agricultural Research Center, Giza, were sterilized by soaking in H_2O_2 (12 % for15 min). The disinfected seeds were transferred into sterilized Petri dishes containing 0.7 % (w/v) agar medium and placed in an incubator in the dark at 28°C for 2 days to allow germination.

2. Protocol in Tissue Culture

After germination period (2 days), 1 cm root tips were excised and placed on the surface of the 10 ml MS medium / test tube (Murashige and Skoog, 1962). This medium was supplemented with 7 g/l agar and 30g/l sucrose. The acidity of the final medium was adjusted to pH 5.6 ± 0.1 prior to adding the agar. Cultures were tested with the five concentrations of saline solution at 0, 1000, 2000, 4000,

6000 and 8000 ppm under three levels (full, double and triple strengths) of potassium nitrate of MS medium on soybean roots *in vitro*. The other micronutrients and organic compounds were added at full strength. Then, root test tubes (90 test tubes for each treatment) were incubated in dark at 28°C for 14 days. After this incubation period, roots were separated from the agar medium, and then collected for morphological parameters, growth, and chemical and nutrient analyses.

3. Measuring Salinity

Total salinity in media after addition of different saline solution concentrations under the three levels of nutrition was measured by its electrical conductivity (Farmnote 2004). Electrical conductivity (EC) is often measured in milliSiemens per meter (mS/m). Table (1) shows electrical conductivity (EC) in media under different treatments.

4. Morphological Parameters and Growth

The morphological parameters (including main root length (cm), secondary roots number and range of secondary root length (cm)/main root) were recorded in 10 roots of each replicate. Growth was measured by fresh and dry weights (mg) of soybean roots. Five roots from each replicate were weighted and then oven dried to constant weight at 70°C for 48 h to determine dry weight. The values of succulence (ratio of fresh weight/dry weight) were calculated according to Tiku equation (Tiku, 1975).

5. Chemical Analyses

Chemical analyses were conducted to determine some biochemical components including proline, free amino acids and crude protein. The following chemical measurements were determined in the fresh harvested roots. Total free amino acids were determined in ethanolic extract by ninhydrin reagent (4 %) according to methods of Plummer (1978). Proline determination was carried out by acid-ninhydrin and acetic acid according to Bates *et al.* (1973).

6. Nutritional Studies

Root samples were used also to examine nutrient contents (including N, Ca, K and Na). The roots were dried at 70°C then thoroughly ground to fine powder, weighed and digested using a mixture of sulfuric acid with hydrogen peroxide according to the

method described by Black *et al.* (1965). In digests, total nitrogen percentage (N) was determined according to the method described by A.O.A.C. (1975) and the crude protein concentration was calculated by multiplying total nitrogen concentration by factor of 6.25. The concentration of sodium (Na^+) and potassium (K^+) were determined in the digested material using flame photometer as described by Eppendrof and Hing (1970). K^+/Na^+ and Ca^{2+}/Na^+ ratios were also calculated for each treatment. Calcium (Ca^{2+}), was assayed using absorption spectrophotometer as reported by Chapman and Pratt (1961).

The experiment was conducted in a complete randomized design with three replicates. The obtained results were subjected to statistical analysis of variance according to method described by Snedecor and Cochran (1982). The statistical analysis of data was done by SAS (1996). Tukey test for separation between means using the following model $Y_{ijk} = \mu + T_i + L_j + TL_{ij} + e_{ijk}$.

RESULTS AND DISCUSSION

1. Morphological Parameters

The data obtained in this experiment are presented in tables (1 – 4). Table (1) indicated the effect of different concentrations of saline solution under three levels of potassium nitrate of MS medium on EC and morphological parameters of soybean roots *in vitro*. Electrical conductivity (EC) gradually increased by increasing saline solution concentration and level of potassium nitrate. Main root length was significantly decreased by saline solution at 8000 and 6000 ppm. From Table (1), it could be observed that the highest positive saline effect on main root elongation (8.24 cm) was found in double strengths of potassium nitrate. These indicate that total salinity in media is considered the limit factor control mineral absorption and translocation. So, decreasing salts in media under high saline treatment allow root to grow and *vice versa* was true. The maximum values of main root length was recorded by saline solution at 2000 and 4000 ppm in the triple and full strengths of potassium nitrate (10.97 and 10.85 cm), respectively. Whereas the opposite trend was occurred by saline solution at 8000 ppm under the same concern of triple and double strengths of potassium nitrate (2.4 and 3.75 cm). This reduction in root elongation could be due to lower K^+ uptake and

consequently inhibited length cell elongation (Kafkafi, 1991).

Concerning secondary root number, saline solution at 4000, 6000 and 8000 ppm had a significant decreased reaching (19.95, 10.99 and 6.7) as compared to the control (25.91). Whereas saline treatments at 1000 and 2000 ppm increased secondary root numbers to 31.37 and 31.04 respectively. Comparing the effect of KNO3 strengths on secondary root numbers, the double strength was found to be surpassed full and triple strength reaching 21.4, 21.0 and 20.4 respectively. Significant increase in secondary roots number (21.4) was noticed by double strength comparing with the other strength. The number of secondary roots was significantly higher in saline solution at 2000 ppm in full and double strengths and lower in saline solution at 8000 ppm in triple strength. Increasing salinity up to 6000 and 8000 ppm under three levels of potassium nitrate adversely affect the range of secondary root length and numbers. Secondary root numbers were found to be inversely proportional to salt concentration. This could be due to decreasing absorption active area under high salinity levels to avoid more Na^+ & Cl^- uptake and accumulation. Generally, plant growth reduction in a saline environment is commonly attributed either to ion toxicity or to a water deficit (Greenway and Munns, 1980; Ibrahim and Shehata, 2000; Ibrahim *et al.*, 2007 and Ibrahim, 2008).

2. Growth and Succulence

Table (2) indicated that fresh and dry weights of soybean roots were significantly decreased by salinization treatments under three levels of potassium nitrate. Control and 1000 ppm treatments in full strength gave the highest values of f.wt. (1620 and 1420 mg) and d.wt. (108 mg), respectively. On the other hand, higher concentrations of saline solution (8000 and 6000 ppm) with the levels of potassium nitrate resulted in the lowest values in f.wt. and d.wt. Increasing level of potassium nitrate adversely affect the fresh and dry weights particularly under high salinity levels. These results indicate that the decrease in f.wt. and d.wt. of soybean roots associated with the level of salinity. At high salinity substrate, growth depression may also originate from inhibited nutrient uptake, transport and utilization in the plants (Cramer and Nowak, 1992). In this respect, high level of salinity had a negative effect on dry weights of both shoot and root (El-Fouly *et al.*, 2002 & 2004).

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Table 1. Effect of different concentrations of saline solution under three levels of potassium nitrate of MS medium on EC and morphological parameters of soybean roots *in vitro*.

Treatment	Electrical Conductivity (EC)			Main root length (cm)				Secondary roots (SR) numbers				Range of SR length (cm)		
(T)	FS	DS	TS	FS	DS	TS	Mean	FS	DS	TS	Mean	FS	DS	TS
Control	5.9	7.7	9.6	8.26	8.69	8.71	8.55	27.37	25.87	24.50	25.91	0.1 - 8.9	0.3 - 8.0	0.2 - 9.0
1000 ppm	7.5	9.4	11.7	8.07	9.63	10.16	9.28	28.25	32.62	32.25	31.04	0.1 - 8.4	0.2 - 8.1	0.1 - 8.8
2000 ppm	9.3	10.7	12.8	9.57	9.78	10.97	10.10	35.62	33.25	25.23	31.37	0.1 - 8.2	0.2 - 7.5	0.2 - 8.5
4000 ppm	12.2	14.3	16.4	10.85	10.55	9.41	10.27	16.62	21.75	21.50	19.95	0.2 - 8.1	0.3 - 6.2	0.2 - 6.1
6000 ppm	15.8	16.8	18.5	4.57	7.04	6.71	6.10	10.75	7.62	14.62	10.99	0.2 - 6.0	0.1 - 5.0	0.1 - 5.0
8000 ppm	21.0	22.4	24.7	6.89	3.75	2.40	4.34	7.87	7.62	4.62	6.70	0.1 - 1.8	0.1 - 1.9	0.1 - 0.6
Mean				8.04	8.24	8.06		21.00	21.40	20.40				
MSD T						0.044				0.068				
MSD L						0.025				0.039				
MSD T * L						0.095				0.147				

Table 2. Effect of different concentrations of saline solution under three levels of potassium nitrate of MS medium on fresh and dry weights (mg), succulence of soybean roots *in vitro*.

Treatment	Root fresh weight, f.wt. (mg)				Root dry weight, d.wt. (mg)				Succulence (f.wt. / d.wt. ratio)			
(T)	FS	DS	TS	Mean	FS	DS	TS	Mean	FS	DS	TS	Mean
Control	1620	1290	1060	1320	108	94	83	95	15.00	13.72	12.77	13.83
1000 ppm	1420	960	650	1010	108	71	69	83	13.15	13.52	9.42	12.03
2000 ppm	1220	910	790	970	80	68	60	69	15.25	13.38	13.16	13.93
4000 ppm	820	720	640	730	63	60	48	57	13.00	12.00	13.33	12.77
6000 ppm	460	440	410	440	44	41	40	42	10.45	10.73	10.25	10.47
8000 ppm	390	384	346	370	37	36	36	36	10.54	10.66	9.61	10.27
Mean	980	784	649		73	62	56		12.88	12.33	11.42	
MSD T			7.22				4.44				0.15	
MSD L			4.15				2.55				0.09	
MSD T * L			15.59				9.59				0.32	

L = Levels of potassium nitrate F = Full strength, D = Double strength, T = Triple strength of potassium nitrate of MS medium.

Data presented in Table (2) show also that raising saline solution at 2000 ppm gave the highest value of succulence. The highest and the lowest values for succulence were recorded (15.25) in saline solution at 2000 ppm in full strength and (9.61) in saline solution at 8000 ppm in triple strength of potassium nitrate, respectively. It is evident that the highest concentration of saline solution and regardless to three levels of nutrition has the most deleterious effect on f.wt., d.wt. and succulence. In other wards, the deleterious effect of salinity on growth (f.wt. and d.wt.) was increased with elerating the level of salinity under levels of potassium nitrate.. At higher rates of saline solution and nutritional level root growth was more restricted than with lower ones. Not all salinity effects are negative; salinity may have some favorable effects on growth and development (Shannon and Grieve, 1999). Similar results were obtained by Seydi *et al.* (2003) and Tawfik *et al.* (2006).

3. Biochemical Aspects

As for the effect of salinity treatments on proline, free amino acids, nitrogen and crude protein concentrations of soybean roots Table (3) reveal that, proline content in soybean roots was accumulated by all saline solution treatments at 4000, 6000 and 8000 ppm. Increasing saline solution concentration increased the proline accumulation. No significant differences were observed with the rest of treatments as compared to the control. Saline solution at 8000 and 6000 ppm gave the highest proline values (8.97 and 6.60 mg/g f.wt.), respectively. As for the levels of potassium nitrate, significant increase in proline concentration was observed by triple strength of potassium nitrate comparing with the other strengths. Hanson and Nelsen (1978) suggested that proline accumulation is merely a symptom of injury. Proline plays an important role in the osmo-regulation and acts as a nitrogen reserve in plants subjected to salt stress (Kalaji and Pietkiewicz, 1993). Accumulation of proline in plant tissue was enhanced by increasing the salinity and/or osmolality of nutrient solution (Tarakcioglu and Inal, 2002 and Ibrahim, 2008).

Generally, a significant increase in proline concentrations could be considered as good parameter for salt tolerance plant (Mumtaz *et al.*, 1995; El-Shamey and Ibrahim, 2004 and Ibrahim *et al.*, 2007). In this respect, Murphy *et al.*, (2003) suggested that proline act as compatible solutes under high salinity levels.

Regarding the effect of saline solution concentrations under three levels of potassium nitrate on free amino acids, nitrogen and crude protein concentrations in soybean roots are presented in Table (3). Data in Table (3) reveal a significant increase in free amino acids by saline solution at 4000 ppm as compared to control and the other treatments. The stimulation effect of full strength of potassium nitrate was obvious in free amino acids as compared to the other strengths. Nitrogen and crude protein % were significantly increased by saline solution at 6000 & 8000 ppm and decreased by the rest of treatments as compared to the control. Since Na^+ in most of the natural salinity cases is accompanied with chloride, competition with nitrate was suggested as a practical agricultural method to prevent salt damage (Kafkafi *et al.*, 1982). Salt stress results in a general decrease in protein synthesis, which could be correlated with a loss of polysomes *in vitro*. In turn, many proteins and mRNAs have been reported to increase or be synthesized *de novo* in response to salt stress (Brady *et al.*, 1984).The reduction in crude protein % under salinity may be due to the disturbance in nitrogen metabolism, inhibition of nitrate absorption and denaturation of the enzymes involved in amino acid and protein synthesis (Sher-Mohamed *et al,.* 1994 and Tawfik *et al.,* 2006). Salt stress results in a general decrease in protein synthesis (Ramagopal and Carr, 1991). Lal and Bhardwaj (1987) observed a decreased in total –N as well as protein –N content of 15 day old *Pisum sativum* seedlings salinized with a mixture of NaCl and $CaCl_2$ with 4 and 8 dS/m salinity. However, an increase in soluble forms of N^+ (NO_3^- and NH_4^+) was observed due to salinity.

4. Mineral Concentrations

The results in Table (4) reveal the effect of saline solution concentrations under three levels of potassium nitrate on Ca^{2+}, K^+, Na^+, Ca^{2+}/Na^+ and K^+/Na^+ in soybean roots. Concentration of calcium in soybean roots was found to be increased by lower salinity (1000 ppm) and decreased by higher salinity (6000 and 8000 ppm). On the other hand, the moderate salinity (2000 and 4000 ppm) gave insignificant effect compared to the control.

All saline solution treatments showed significant reduction in K% when compared to the control. Meanwhile, opposite trend was observed in Na%. The general response of many crop plants to a

moderate increase in external salinity was increased plant K^+ levels and reduced Na^+ concentrations.

The increment in saline solution caused the highest sodium concentration in soybean roots. The Ca^+/Na^+ and K^+/Na^+ ratios in soybean roots were higher in the control than the treatments of saline solution. Accumulation of sodium in soybean roots was enhanced by increasing saline solution concentration. In general, Ca^{2+} and K^+ concentrations as well as Ca^{2+}/Na^+ and K^+/Na^+ ratios were decreased by increasing saline solution concentration. Regarding the effect of potassium nitrate levels, the lowest values of Ca %, Ca^{2+}/Na^+ and K^+/Na^+ ratios were recorded by the full strength as compared to double and triple strength.

High Na^+ concentrations in the substrate inhibit uptake and transport of Ca^{2+} and may therefore induce calcium deficiency in plants growing in substrates with low Ca^{2+} concentrations or low Ca^{2+}/Na^+ ratios (Lynch and Läuchli, 1985). Grattan and Grieve (1999) stated that salinity dominated by Na^+ salt not only reduces Ca^{2+} availability but also reduces Ca^{2+} transport and mobility to growing regions of the plant, which affect the quality of both vegetative and reproductive organs. Also, nutrient additions have been more successful in improving the case.

Roots Na^+ concentration increased while K^+ concentration decreased with increasing salinity, hence K^+: Na^+ ratio decreased significantly. The potassium concentration in the sensitive species was decreased with salinity (Subbarao *et al,* 1990). Similar results have been found by Tarakcioglu and Inal (2002). This might be due to antagonistic interaction between Na^+ and K^+ (Ohno and Grunes, 1985). Potassium has substantial effect on enzyme activation, protein synthesis, photosynthesis, stomatal movement and water relation (turgor regulation and osmotic adjustment) in plants (Marschner, 1995). Tester and Davenport (2003) reported that more than 50 enzymes are activated by K^+ and Na^+ can not substitute in its role. Thus, high levels of Na^+ or low K^+: Na^+ ratios can disrupt various enzymatic processes in the cytoplasm. In view of the fact that high NaCl treatments impair K^+ nutrition of plants, it was suggested that K^+ deficiency at the cellular level might be a contributory factor to salt induced oxidative stress and related cell damage. Therefore, improving K^+ nutrition of plants under salt stress could be essential to minimizing oxidative cell damage (Shen *et al.*, 2000). Maintenance of

adequate cytoplasmic levels of K^+ and K^+ /Na^+ ratios in the cell is essential for normal functioning under saline conditions (Greenway and Munns, 1980).

In general, it can be concluded that moderate salinity positively affected growth, some biochemical components and nutrients uptake of soybean roots. The reduction in growth under high salinity levels could be due to disturbance in mineral uptake and protein synthesis. However, feeding with potassium nitrate could partially counteract the negative effect of saline solution on nutrients uptake through improving root growth. Finally, the results obtained in this research not only confirmed the well established fact that nutrition could mitigate the detrimental effects of salinity on growth and nutrient uptake, but also indicated interesting results in terms of the significant and positive crop response to nutrient application under highly saline soil than on the non-saline one.

Table 3. Effect of different concentrations of saline solution under three levels of potassium nitrarte of MS medium on N, proline, free amino acids and crude protein of soybean roots in *vitro* .

Treatment	N %				Proline (mg / g f.wt.)				Free amino acids (mg / g f.wt.)				Crude protein %			
(T)	FS	DS	TS	Mean	FS	DS	TS	Mean	FS	DS	TS	Mean	FS	DS	TS	Mean
Control	2.35	2.91	2.88	2.71	5.54	5.89	4.34	5.26	115.1	79.0	104.9	99.6	14.68	18.18	18.00	16.93
1000 ppm	2.40	2.75	2.55	2.56	4.38	5.30	5.58	5.08	110.5	88.9	74.5	91.3	15.00	17.18	15.93	16.00
2000 ppm	2.60	2.38	2.67	2.55	5.65	4.76	4.43	4.95	89.5	101.2	103.2	98.0	16.25	14.87	16.68	15.93
4000 ppm	2.53	2.69	2.72	2.64	5.79	5.88	5.97	5.88	103.5	95.0	120.3	106.3	15.81	16.81	17.00	16.50
6000 ppm	2.45	3.28	3.77	3.16	5.12	6.08	8.61	6.60	72.6	67.4	78.3	72.8	15.31	20.50	23.56	19.75
8000 ppm	3.30	3.67	3.78	3.58	7.88	9.60	9.44	8.97	97.6	80.2	56.4	78.1	20.62	22.93	23.43	22.37
Mean	2.60	2.64	3.06		5.6	6.0	6.061.1		98.1	85.3	89.6		16.25	18.37	14.12	
MSD T			0.050				2.140				4.850				0.050	
MSD L			0.028				1.229				2.789				0.030	
MSD T * L			0.107				4.620				10.480				0.117	

Table 4. Effect of different concentrations of saline solution under three levels of potassium nitrate of MS medium on Ca, K, Na, Ca / Na and K / Na ratios of soybean roots *in vitro* .

Treatment	Calcium (Ca) %				Potassium (K) %				Sodium (Na) %				Ca / Na ratio				K / Na ratio			
(T)	FS	DS	TS	Mean	FS	DS	TS	Mean	FS	DS	TS	Mean	FS	DS	TS	Mean	FS	DS	TS	Mean
Control	1.75	1.90	1.95	1.86	3.29	3.62	4.24	3.72	0.72	0.97	1.23	0.10	2.43	1.96	1.58	1.99	4.57	3.73	3.44	3.91
1000 ppm	1.75	2.00	2.05	1.93	2.94	3.62	4.05	3.54	1.11	1.05	0.92	1.03	1.57	1.90	2.23	1.90	2.65	3.44	4.40	3.49
2000 ppm	1.70	2.05	1.80	1.85	2.92	3.40	3.40	3.24	1.36	1.47	1.42	1.42	1.25	1.39	1.27	1.30	2.14	2.31	2.39	2.28
4000 ppm	1.65	2.05	1.85	1.85	3.05	3.59	3.37	3.34	2.10	1.99	1.88	1.99	0.78	1.03	0.98	0.93	1.45	1.80	1.79	1.68
6000 ppm	1.54	1.78	1.73	1.68	2.67	3.80	3.84	3.44	2.31	2.39	2.23	2.31	0.66	0.74	0.77	0.72	1.16	1.59	1.72	1.49
8000 ppm	1.20	1.80	1.75	1.58	2.24	2.81	2.81	2.43	2.47	2.60	2.42	2.42	0.48	0.76	0.72	0.65	0.91	1.19	1.16	1.09
Mean	1.60	1.93	1.85		2.85	3.47	3.47		1.68	1.70	1.68		1.19	1.29	1.26		2.15	2.34	2.48	
MSD T			0.05				0.109				0.05				0.047				0.048	
MSD L			0.03				0.060				0.03				0.027				0.027	
MSD T * L			0.10				0.230				0.10				0.102				0.103	

L =Levels of potassium nitrate F = Full strength, D = Double strength, T = Triple strength of potassium nitrate of MS medium.

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دور نترات البوتاسيوم فى تقليل التأثيرات الضارة للاجهاد الملحى فى جذور فول الصويا معمليا

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تم دراسة تأثير التركيزات المختلفة للمحلول الملحي على نمو وتطور جذور فول الصويا معمليا تحت ثلاث مستويات من نترات البوتاسيوم لبيئة مورشيجى وسكوج. هذه الدراسة تشتمل أيضا على الاستجابة المورفولوجية لجذور فول الصويا للمعاملات السابقة وعلاقتها بالوزن الطازج والجاف والعصارية ومؤشر تحمل الملوحة وبعض المكونات الكيموحيوية والمعدنية. تم تقييم تحمل الملوحة بقدرة جذر النبات على النمو تحت ظروف الإجهاد الملحى.

كان نمو الجذور وامتصاص عناصر الكالسيوم والبوتاسيوم تحت المعدلات العالية من المحلول الملحي والقوة الغذائية من نترات البوتاسيوم أكثر تقيدا من المعدلات الأقل. أشارت النتائج إلى إن النقص فى الوزن الطازج والجاف للجذور ارتبط بمستوى الملوحة المرتفع. أعطى المحلول الملحي بتركيز 2000 جزء فى المليون خصائص مورفولوجية جيدة بالإضافة الى محتوى البرولين و الاحماض الامينية الحرة. زيادة تركيز المحلول الملحي حتى 4000 جزء فى المليون والتركيز العالى من نترات البوتاسيوم إدى الى نقص النسبة المئوية للنيتروجين والبروتين الخام ولكن فى المحلول الملحى 6000 و8000 جزء فى المليون كانت على النقيض. كانت نسب الكالسيوم/الصوديوم والبوتاسيوم/الصوديوم فى معاملات الكنترول أعلى من معاملات المحلول الملحي. وقد لوحظت زيادة معنوية فى تركيز البرولين تبدأ من المحلول الملحى بتركيز 4000 حتى 8000 جزء فى المليون. على وجه العموم يمكن اعتبار التغيرات السابقة أداة جيدة على تحمل الملوحة.