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Growth of Sugar Beet as Affected by Diluted Sea Irrigation Water and Possible Enhancement of Salinity Stress Tolerance with KMP Foliar Fertilization

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ABSTRACT

A greenhouse pot experiment was conducted with three commercial sugar beet varieties 'Marathon', 'Armure' and 'Francesco' to study the effect of diluted Red Sea water as irrigation water on the growth parameters and dry weight (DW) accumulation, and whether KMP foliar fertilization would increase plant tolerance to salinity stress. There were slight variations in growth parameters between the three varieties at either low or high salinity stress. Significant differences were observed in the root diameter and shoot and root fresh weight (FW) and shoot DW. Irrigation with saline water negatively affected all growth parameters (shoot length, number of leaves/plant, root length and diameter, FW and DW). As the salinity of irrigation water increased so growth parameters decreased. KMP foliar fertilization increased the K concentration in the leaves of treated plants and significantly increased root diameter and the FW and DW of roots and shoots.

Keywords: potassium foliar nutrition, salinity tolerance increase

INTRODUCTION

Salinity is an abiotic stress that negatively affects agricultural productivity the world over, especially in arid and semi-arid regions in the Near East and North Africa. Salinity stress is proportional to salt concentration in the irrigation water (Abou-Hadid 2003). Accumulated salts lead finally to growth reduction due to the osmotic potential in the root-zone (Kachout *et al*. 2009) which in turn result in reduced crop productivity. Overpopulation and the increased gap between agricultural productivity and food and feed needs mandate finding new technologies that reduce the harmful effects of salinity and increase production of unit areas.

Sugar beet is the second source for sugar production in Egypt. Sugar beet plants have the ability to tolerate moderate soil salinity stress (Abdel-Mawly and Zanouny 2004). However, water quality and nutrient balance are still the major limiting factors for crop production in most soils (El-Etreiby 2000; Etesami *et al*. 2010). A high salt concentration in the root zone restricted K-uptake by the roots (Shehata *et al.* 2000; Lee *et al*. 2007) and in turn, K content in shoots (Shaaban *et al*. 2008). Because of its biochemical role in sugar transport, studies have mostly concentrated on the effect of K application on the chemical composition of sugar beet plants grown under salinity stress conditions (El-Harriri and Gobarh 2001; Khalil *et al.* 2001; Abdel-Mawly and Zanouny 2004; Feckova *et al*. 2005).

Since saline water has become an alternative source for sugar beet irrigation in newly reclaimed soils, the present work aimed at assessing the growth of the most popular sugar beet varieties in Egypt under diluted seawater irrigation conditions and whether their tolerance could be increased by a foliar spray of potassium mono-phosphate fertilizer.

MATERIALS AND METHODS

A pot experiment was conducted in the greenhouse of the National Research Centre, Cairo, Egypt during the winter season of 2007/2008, with three sugar beet (*Beta vulgaris* L.) varieties ('Marathon', 'Armure' and 'Francesco') to evaluate the influence of irrigation with saline water on growth parameters and whether supplementation of KMP foliar sprays could increase plant resistance to salinity.

Cultivation

The experiment included 24 treatments which were the combination of four treatments of irrigation by saline water, three sugar beet varieties and two PK treatments. The experimental design was a split-split plot in 3 replicates. Ten metallic pots 35 cm in diameter and 50 cm deep were used. Each pot contained 30 Kg of air-dried clay loam soil. The inner surface of the pots was coated with three layers of bitumen to prevent direct contact between soil and metal. Two kg of gravel (particles about 2-3 cm in diameter), were placed at the bottom allowing for the movement of water from the base upward. Sugar beet seeds were sown on December 15 and seedlings were thinned twice 15 and 30 days after sowing, leaving two plants per pot.

Fertilization

Calcium super phosphate (15.5% P_2O_5) and potassium sulfate (48.5% K_2O) at a rate of 3.0 and 1.5g.pot^{-1}, respectively were added before sowing. Ammonium sulfate (20.5% N) at a rate of 6.86g. pot^{-1} was added in two equal splits, the first at 21 days from sowing and the second two weeks later.

Sugar beet varieties

Seeds of the three sugar beet varieties 'Marathon', 'Armure' and 'Francesco' were purchased from the seed collection of the Agricultural Research Centre, Ministry of Agriculture, Giza, Egypt.

Received: 18 March, 2010. Accepted: 15 May, 2010.

Original Research Paper

Treatments

a) Diluted Red seawater was applied at 3.13, 5.25 and 12.50 $dS.m^{-1}$ as irrigation water. Chemical composition of the original sea water is shown in **Table 1**. Salinity treatments were started 21 days after sowing, irrigation once with diluted seawater and next with tap water (0.3 $dS.m^{-1}$), alternatively until harvest.
b) A potassium monophosphate spray was applied twice at 200 $mg.l^{-1}$, 21 days after sowing and two weeks later, in which the control plants received the same amount sprayed, except that tap water was used.

Sampling and analysis

Soil: A representative soil sample was taken from the experimental units, air dried, ground and analyzed according to the methods of Chapman and Pratt (1978). The chemical and physical properties of the soil are shown in **Table 2**.

Vegetative tissue: recent fully mature leaf samples were taken. Samples were washed with tap water, 0.01 N HCl and double distilled water, respectively, dried at 70°C for 24 hrs, weighed and ground. A part of the dry leaves was ashed in a Muffel furnace at 550°C for 6 hrs. The ash was digested in 3 N HNO_3 and the residue was then suspended in 0.3 N HCl (Chapman and Pratt 1978).

Nutrient measurements: Phosphorus was photometrically determined using the molybdate-vanadate method according to Jackson (1973). Potassium, sodium and calcium were measured using a Dr. Lang M8D flame-photometer. Magnesium, Fe, Mn, Zn and Cu were determined using an atomic absorption spectrophotometer (Perkin-Elmer 100 B).

Evaluation of nutrient status: Soil nutrient concentrations were evaluated according to Ankerman and Large (1974).

Growth parameters studied

The growth parameters studied were shoot height, number of green leaves and leaf area. After plants were harvested, the parameters determined were shoot and root fresh weight (FW), and shoot and root dry weight (DW).

Table 1 Chemical composition of the original Red Sea water.

Salinity	3.5%
pH	8.0
Element	**Concentration ($mg.l^{-1}$)**
Na	10950
Cl	19500
Mg	1300
K	400
Ca	450
N	17
P	Trace
Fe	Trace
Mn	Trace
Zn	Trace
Cu	Trace
B	4.5

Table 2 Chemical and physical characteristics of the soil.

Physical characteristics	Nutrient concentrations
pH 8.3	Exchangeable macronutrients (mg.100 g^{-1} soil)
E.C. ($dS.m^{-1}$) 0.8	P 5.2*
$CaCO_3$ (%) 1.6	K 37.9*
O.M. (%) 0.1**	Mg 30.7*
Sand (%) 14.0	Available micronutrients ($mg.kg^{-1}$ soil)
Silt (%) 28.0	Fe 11.0*
Clay (%) 58.0	Mn 9.0*
Texture: clay loam	Zn 3.3*
	Cu 10.2*

* Adequate ** Low

Statistical analysis

Collected data were subjected to the statistical analysis of Snecdor and Cochran (1990) to calculate replicate means and LSD ($P \leq 0.05$) for different treatments.

RESULTS AND DISCUSSION

Varietal differences

Growth parameters of the three sugar beet varieties as affected by varietal differences are shown in **Table 3**. There were significantly differences in root diameter, and root and shoot FW. The best root diameter was in 'Armure' while 'Marathon' had superior root FW while 'Francesco' had the highest shoot DW (**Fig. 1**). There were no significant differences in the root DW between the three varieties. Differences in growth parameters and yield between sugar beet varieties are common (Feckova *et al*. 2005). However, these differences were considered to be minor depending on the narrow genetic base of the commercial varieties (McGrath *et al*. 1999).

Effect of salinity on sugar beet growth parameters

Irrigation with seawater negatively affected sugar beet growth parameters, including shoot height, number of leaves /plant, root length and diameter and root and shoot FW (**Table 4**). A gradual decrease in these parameters was observed as the salinity of irrigation water increased and the parameters most affected were shoot height and shoot and root FW. Plant DW decreased dramatically as the salinity of irrigation water increased (**Fig. 2**). This means that osmosis

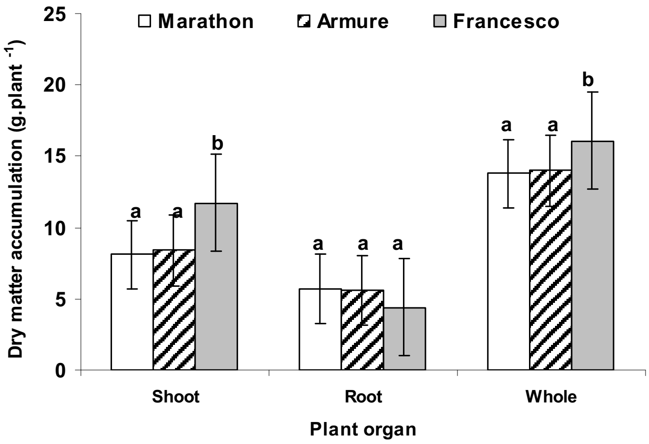

Fig. 1 Dry matter accumulation in sugar beet plants as affected by varietal differences. Values represent the mean ± standard error (n = 3). Data with similar letters are not significantly different at $P \leq 0.05$.

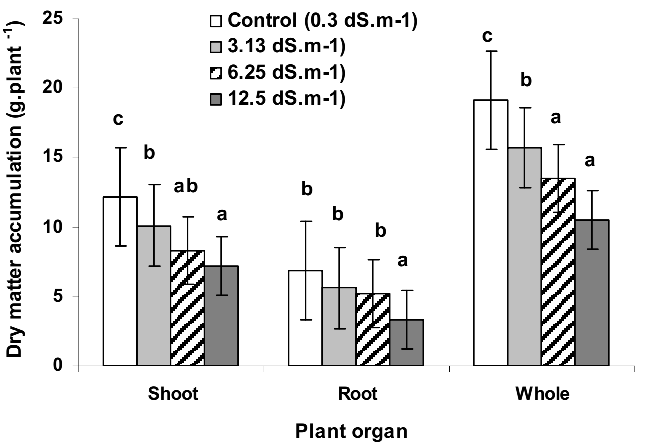

Fig. 2 Dry matter accumulation in sugar beet plants as affected by salinity levels. Values represent the mean ± standard error (n = 9). Data with similar letters are not significantly different at $P \leq 0.05$.

Table 3 Growth parameters of the three sugar beet varieties as affected by varietals differences.

Variety	Shoot height (cm)	No. of leaves per plant	Root		Fresh weight		
			Length (cm)	Diameter (cm)	Root $g.plant^{-1}$	Shoot $g.plant^{-1}$	Whole $g.plant^{-1}$
Marathon	30.8 a	12.7 a	15.3 a	2.7 ab	36.8 b	52.5 a	89.3ab
Armure	32.3 a	12.9 a	14.8 a	3.0 b	30.2 a	67.6 b	97.8 b
Francesco	34.1 a	13.8 a	15.7 a	2.6 a	25.9 a	58.2ab	84.1 a
$LSD_{0.05}$	3.20	1.39	1.86	0.32	4.97	9.48	14.87

Data with similar letters are not significantly different, $P \leq 0.05$

Table 4 Response of sugar beet plants to different salinity levels of the irrigation water.

Salinity $dS.m^{-1}$	Shoot height (cm)	No. of leaves per plant	Root		Fresh weight		
			Length (cm)	Diameter (cm)	Root $g.plant^{-1}$	Shoot $g.plant^{-1}$	Whole $g.plant^{-1}$
0.30	36.6 c	15.2 a	18.2 b	3.0 b	39.7 b	74.3 b	114.0 c
3.13	33.3 bc	12.9 a	17.1 b	3.1 b	37.8 b	59.0 ab	96.8 b
6.25	31.6 b	12.5 a	13.8 a	2.7 a	24.3 a	58.4 ab	82.7 ab
12.50	28.0 a	11.9 b	12.2 a	2.3 a	22.2 a	46.1 a	68.3 a
$LSD_{0.05}$	3.46	2.13	2.79	0.36	4.83	16.3	21.9

Data represent means of the three varieties, n= 9

Data with similar letters are not significantly different, $P \leq 0.05$

Table 5 Response of sugar beet plants grown under salinity stress of irrigation water to KMP foliar fertilization.

KMP $mg.l^{-1}$	Shoot height (cm)	No of leaves per plant	Root		Fresh weight		
			Length (cm)	Diameter (cm)	Root $g.plant^{-1}$	Shoot $g.plant^{-1}$	Whole $g.plant^{-1}$
0	31.3 a	12.8 a	14.2 a	2.6 a	25.8 a	52.3 a	78.1 a
200	33.5 a	13.4 a	16.4 a	2.9 a	36.2 b	66.6 b	102.8 b
$LSD_{0.05}$	3.53	0.74	3.01	0.77	9.31	7.01	4.13

Data represent means of the three varieties, n = 9

Data with similar letters are not significantly different, $P \leq 0.05$.

KMP = potassium monophosphate

in the root medium restricted water and nutrient utilization by plant roots (Kachout *et al*. 2009), which resulted in dwarfed tops, reduced leaf number/plant and thinner and shorter roots than the control plants. This can be attributed to the negative effect on water adjustment in plant tissues (Katerji *et al*. 1997; Medrano *et al*. 2002). Irrigation with saline water decreased macro- and micronutrient concentrations in sugar beet shoot tissues (Hussein *et al*. 2008). Shaaban *et al*. (2008) stated that N, P, K Mn and Cu uptake by barley roots declined as the salinity of irrigation water increased. An increase in sodium concentration in plant tissues was accompanied with a decrease in potassium (**Fig. 3**), which may have slowed down many of the biochemical processes which led to growth retardation and reduction in dry matter accumulation.

Response of stressed plants to KMP foliar fertilization

Macro- or micronutrient foliar fertilization can be a useful technique to improve the nutritional status of plants grown under salinity stress conditions (El-Maghraby *et al*. 1998; Shaaban *et al*. 2004). Potassium monophosphate (KMP) foliar fertilization enhanced the growth parameters of sugar beet irrigated by saline water (**Table 5**) although it did not significantly affect shoot height, leaf number/plant or root length and diameter. However, the shoot and root FW and DW showed significant positive responses to the foliar spray (**Fig. 4**). Leaf Na concentrations of the plants grown under salinity stress received no KMP foliar sprays surpassed the concentrations in plants that received foliar sprays (**Fig. 3**). However, the opposite was true for potassium concentrations. Since K was reported to be the most affected nutrient in the tissues of plants grown under salinity stress conditions (Hussein *et al*. 2008), thus KMP foliar application could increase K concentrations in the plant tissues. The small quantities of K absorbed by the leaves might accelerate the biochemical processes that led to an increment of other elements' uptake and translocation (Shaaban *et al*. 2008), which finally improved the nutrient balance within the plant tissues and led to better growth (Shaaban *et al*. 2004; Hussein *et al*. 2008).

CONCLUSIONS

From the present work it can be concluded that:

- The popular sugar beet varieties in Egypt 'Marathon', 'Armure' and 'Francesco' differ slightly regarding their growth parameters.
- Salinity with irrigation water negatively affected all growth parameters of sugar beet plants and the higher the level of salinity the greater the negative effect.
- Foliar fertilization with potassium monophosphate (KMP) can increase K concentrations in plant tissues and lead to significant increases in shoot and root FW and DW, which are considered as indictors of salinity tolerance.

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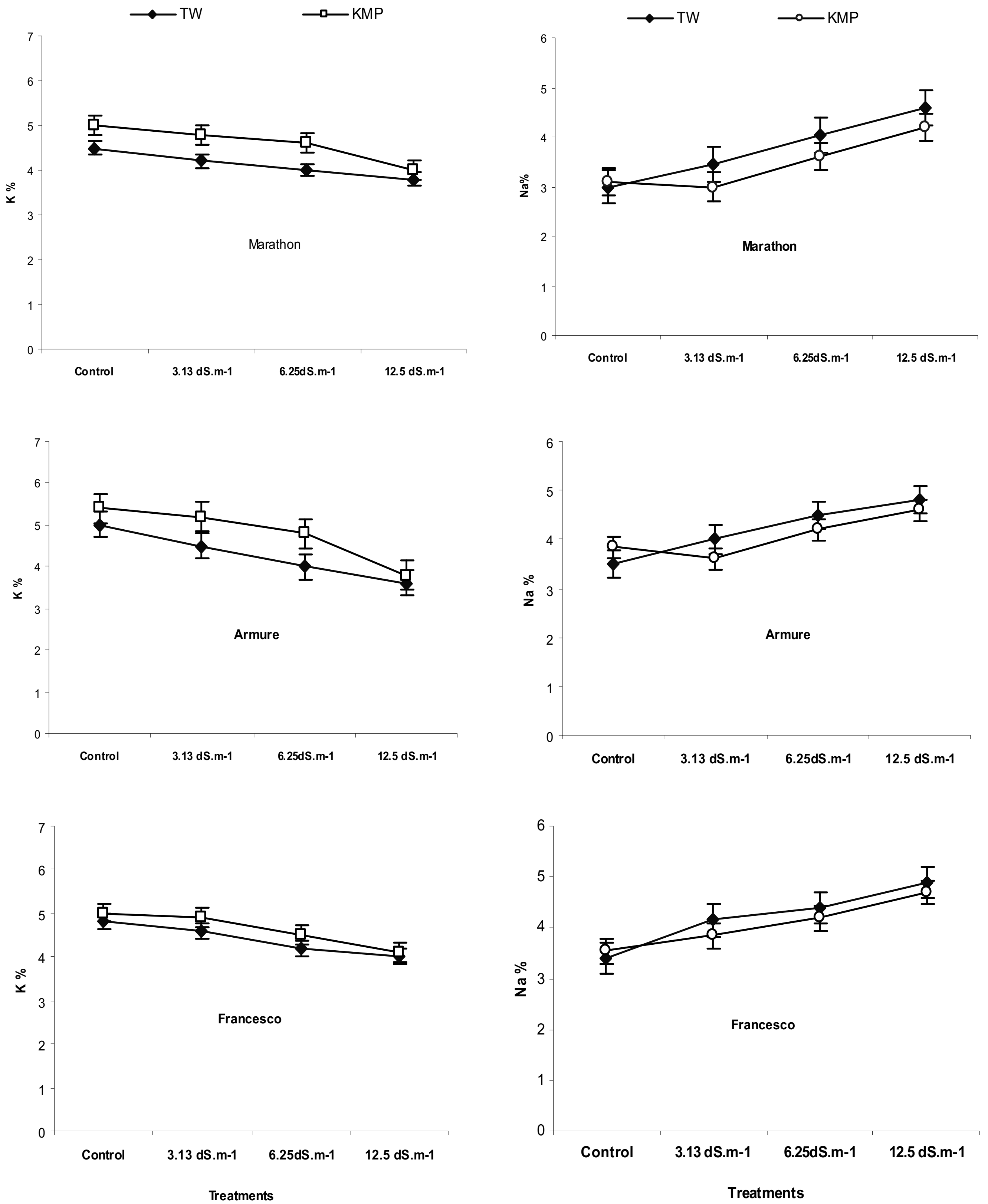

Fig. 3 Potassium (K) and sodium (Na) concentrations in the leaves of sugar beet varieties as affected by salinity levels in the irrigation water and KMP foliar fertilization. Values represent the mean ± standard error (n = 3). Data with similar letters are not significantly different at $P \leq 0.05$. TW = tap water, KMP = potassium monophosphate.

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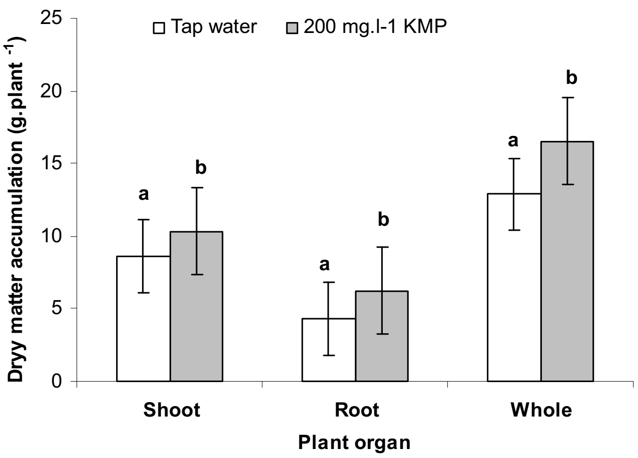

Fig. 4 Dry matter accumulation in sugar beet plants grown under salinity stress conditions of irrigation water as responded to KMP foliar fertilization. Values represent the mean ± standard error (n = 9). Data with similar letters are not significantly different at $P \leq 0.05$.

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