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## Phosphorous Uptake of Gourds Species and Watermelon under Different Salt Stress

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**Abstract:** Phosphorous uptake of 7 different gourd genotypes [*Cucurbita maxima*, *C. moschata*, *Luffa cylindrica*, *Benincasa hispida*, *Lagenaria siceraria* landraces (SKP and BR) and *Lagenaria siceraria* hybrid (FRGold)] and a watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai] cultivar Crimson Tide grown under five different saline conditions for 30 days was investigated. Salinity stress was induced by continuous irrigation with saline water having EC of 0.5, 4, 8, 12 and 16 dS m<sup>-1</sup>. P uptake was affected by plant species and salinity levels. Salinity stress has resulted in an increase in P content of gourd leaves. For example, P content of BR at 16 dS m<sup>-1</sup> was three times higher than that of control (0.5 dS m<sup>-1</sup>) whereas salt resistant genotypes such as *C. moshata* and *maxima* showed little increase. Results showed that smaller change in P content could be an indication of stronger resistance to salinity stress, since excessive P uptake under salinity stress may cause P toxicity.

**Key words:** Gourds, P uptake, rootstocks, salinity stress, watermelon

### INTRODUCTION

Salinity is a serious problem in arid and semi-arid regions and a very large area is prone to salinity due to irrigation. On the other hand, in many irrigated areas of the arid and semi-arid regions, farmers are forced to use saline water to irrigate their crops due to an inadequate supply of fresh water. The interaction between salinity and nutrient uptake, including P by plants is a complex task. The interaction is highly dependent upon the plant species (or cultivar), plant developmental age, the composition and level of salinity and the concentration of P in the substrate (Grattan and Grieve, 1999). Crop performance may be adversely affected by salinity-induced nutritional disorders. These disorders may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant. For example, salinity reduces phosphate uptake and accumulation in crops grown in soils primarily by reducing phosphate availability but in solution cultures ion imbalances may primarily result from competitive interactions (Grattan and Grieve, 1999).

At low P, NaCl had no significant effect on shoot concentrations of P; however, root P concentrations tended to decrease with increasing NaCl level (Rogers *et al.*, 2003). Similarly, at low P concentration as in arid regions soils, P uptake and translocation from root to shoots in cotton was inhibited by salt treatments (Martinez and Lauchli, 1994). In contrast, increasing external P can reduce salt induced disorders regarding

low P uptake and increase translocation efficiency (Khalifa *et al.*, 2000). Such increase in P content and growing performance may be attributed to the exchange of limiting factor from P deficiency to salt stress as pointed out by Champagnol (1979). These results have important implications for salt affected soils of arid and semi-arid regions regarding to very low level of available P content and this requires larger amount of P fertilizer usage, preferably foliar application, to minimize salt stress (Kaya *et al.*, 2001). Because, P availability is reduced in saline soils by not only ionic strength effects that reduce the activity of phosphate but also sorption processes that scavenge P from the soil solution. However, P addition to saline soils increased crop growth and yield in 34 of 37 crops studied but this did not necessarily increase crop salt tolerance (Champagnol, 1979).

Azcon and ElAtrash (1997) studied the effect of both fertilization and mycorrhizal inoculums on plant growth and nutritional status under various type and degrees of salinity and they found that mycorrhizal inoculation protected the plants from salt stress more efficiently than any amount of plant-available P in soil, particularly at the highest salinity level applied. Similar results were also reported for phosphorous fertilizer applied and arbuscular mycorrhiza inoculated wheat under greenhouse conditions (Mohammad *et al.*, 2003). On the other hand, foliar application of KH<sub>2</sub>PO<sub>4</sub> ameliorated the negative effects of salinity on water consumption, plant growth and fruit yield of strawberry (Kaya *et al.*, 2001).

Navarro *et al.* (2001) reported that salinity decreased Pi uptake by melon seedlings (*Cucumis melo* L. cv. Galia) grown hydroponically at low Pi (high affinity uptake mechanism), although no specific competitive inhibition of Pi uptake by Cl<sup>-</sup> was observed. When plants were grown with high Pi, the uptake of Pi through the low affinity system was increased. Salinity also reduced the phosphorus flux, as Pi, through the xylem. They hypothesized that high levels of NaCl decrease the mobility of Pi stored in vacuoles and as a result, inhibit export from this storage compartment to other parts of the plant.

Literatures reviewed showed that there is very limited knowledge about the response of gourds to salinity and resistant gourds may be used as rootstock for melon or watermelon (Ruiz and Romero, 1999; Yetişir and Sari, 2003; Colla *et al.*, 2006). The aim of this study is to determine the effect of salt stress on P uptake by various gourd species and a watermelon differing their salinity tolerance and select resistant rootstocks for watermelon.

## MATERIALS AND METHODS

**Plant material and growth conditions:** The watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai] cultivar Crimson Tide (C. Tide) and 7 different gourd species were used as plant materials. Name, definition and source of rootstocks are presented in Table 1. The experiment was carried out in a greenhouse (temperature 28/20°C and 60-70% relative humidity). Seed were sown in 2:1 peat (EC: 0.36 dS m<sup>-1</sup>, pH: 6.0-6.5); perlite mixture. Seeds of *Luffa cylindrica* and *Benincasa hispida* were sown 7 days earlier than seeds of other gourd species and watermelon because they need longer time for germination and emergence (Yetisir and Sari, 2003). Seedlings at two true leaf stage were transplanted to 2 L pots filled with mixture of peat and perlite in ratio of 1:1 amended with 0.8 g N L<sup>-1</sup>, 0.175 g P L<sup>-1</sup>, 0.332 g K L<sup>-1</sup> and 0.4 g Ca L<sup>-1</sup>. Seedlings were irrigated with tap-water with EC = 0.5 dS m<sup>-1</sup> and pH = 7.0-7.4 for one week then salt application was begun. Plants were irrigated with five different saline conditions by 2 days interval, which derived from tap water by use of NaCl. EC of irrigation water was adjusted to 0.5 (control), 4.0, 8.0, 12.0 and 16.0 dS m<sup>-1</sup>, respectively. Half of the dosage (control, 2.0, 4.0, 6.0 and 8 dS m<sup>-1</sup>) was used during the first week of salt application in order to facilitate the adaptation of plants to high salt treatments (EC > 4 dS m<sup>-1</sup>). Excess of irrigation water was allowed to freely drain from the bottom of the pots for avoiding excessive accumulation of salt in root zone and thus the EC of growth medium was kept constant during the

Table 1: Name, definition and source of gourd genotypes

Gourd genotypes	Definition	Source
<i>Luffa cylindrica</i> (LCY)	Landrace	Hatay - Turkey
<i>Lagenaria siceraria</i> Birecik (BR)	Landrace	Şanlıurfa-Turkey
<i>Lagenaria siceraria</i> (SKP)	Landrace	Adana-Turkey
<i>Cucurbita maxima</i> (CMA)	Landrace	Hatay-Turkey
<i>Cucurbita moschata</i> (CMO)	Landrace	Hatay-Turkey
FR Gold (FRG)	<i>Lagenaria</i> hybrid	Korea
<i>Benincasa hispida</i> (BH)	Landrace	Ankara-Turkey

experiment. EC of drainage water was measured by means of hand EC meter. The experimental design was split plots. Each treatment was replicated three times with 3 plants. At the end of the 4 weeks (beginning of flowering stage in the control treatment) 5th and 6th leaves from the top or all leaves for plants subjected to high salinity were sampled.

**Analytical methods:** After elimination of possible contaminants, samples were oven-dried at 70°C for 48 h and particle size (<0.5 mm) was reduced. Powdered samples were digested with HNO<sub>3</sub> + HClO<sub>4</sub> mixture (Jones, 1991) and analyzed for P by vanadomolybdophosphoric acid method (Kuo, 1996). Ca, Mg, Na, K, Fe, Cu, Mn and Zn contents of leaves for control treatment were determined by ICP-AES to check the deficiency of corresponding elements for better understanding the effect of salt stress on P uptake.

## RESULTS

**Growing performance:** The interaction between salinity level and growth (shoot and root) rate was highly dependent upon salinity level and species (Fig. 1a and b). Visual observation showed that up to 8 dS m<sup>-1</sup> there was no toxic effect of either Na or Cl<sup>-</sup> ion. Majority of leaves were scorched due to ionic toxicity above 12 dS m<sup>-1</sup> and only very little growth was observed at the highest level of salinity. As the salinity increased, both root and shoot growth decreased drastically (Fig. 1a and b).

Since shoot and root growth are specific for each species, average relative decrease was considered for a sensible comparison of their resistance to salinity. Resistance of gourds against increasing level of salinity can be ordered as CMA > CMO > SKP > BR > FRG ≥ LCY > CT > BH as average decrease in shoot growth considered 34.55, 40.39, 47.52, 48.77, 50.24, 50.72, 53.44 and 62.89%, respectively. As species considered *Cucurbita* (CMA, CMO) was the most resistant to salinity and followed by *Lagenaria* (BR, FRG, SKP), *Luffa* (LCY), *Citrullus* (CT) and *Benincasa* (BH). However, growing performance of root was different than that of shoot growth and generally smaller growth losses were observed. The order was: SKP > CMO > CMA > BR >

Table 2: Elemental composition of gourds and watermelon (CT) in control treatment

Species	Ca (%)	K (%)	Mg (%)	Na (%)	Fe (mg kg <sup>-1</sup> )	Cu (mg kg <sup>-1</sup> )	Mn (mg kg <sup>-1</sup> )	Zn (mg kg <sup>-1</sup> )
BH	3.20	0.84	0.750	0.024	89.8	5.75	137.1	54.1
BR	1.28	1.20	0.246	0.017	115.6	6.43	141.2	65.3
CMA	2.07	1.06	0.444	0.015	133.0	10.25	259.7	92.6
CMO	2.70	1.32	0.500	0.021	131.4	8.10	163.5	87.3
CT	2.93	0.98	0.372	0.047	104.9	7.43	104.9	79.3
FRG	2.17	0.90	0.374	0.020	140.7	5.85	162.4	75.4
LCY	3.18	1.49	0.494	0.009	147.4	6.90	288.1	82.0
SKP	1.35	1.12	0.235	0.021	106.2	8.58	222.8	127.8

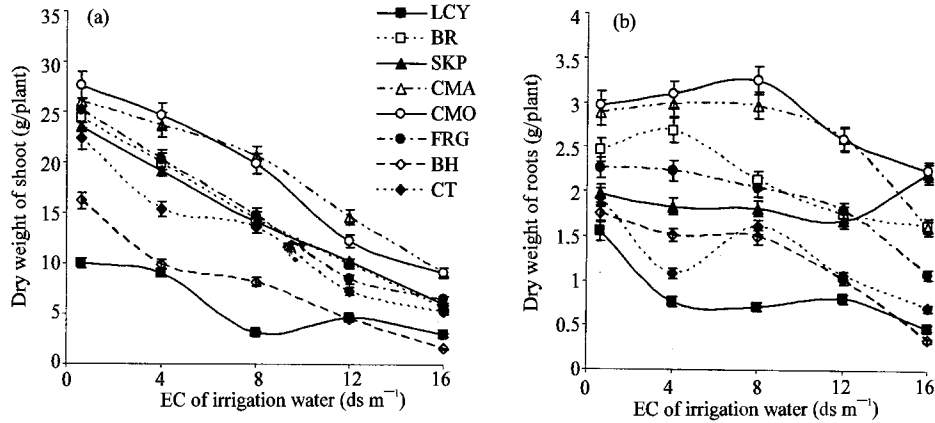


Fig. 1: The effect of salinity (a) on shoots (b) root growth of gourds and watermelon (CT)

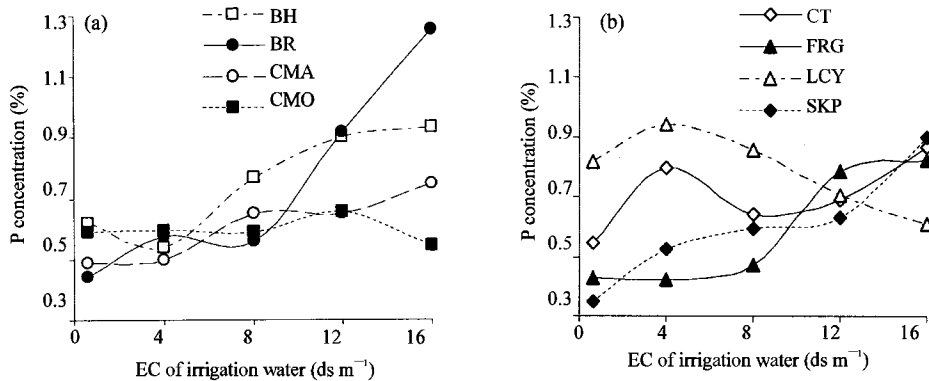


Fig. 2: Effect of salinity on P content of leaves in various (a) gourds and (b) watermelon (CT)

FRG > BH > CT > LCY (4.44, 5.98, 11.72, 16.67, 20.80, 37.36, 42.36 and 55.65%, respectively). The response of CMO, CMA and BR to increasing salinity was different from the others. There was an increase in the root weight up to 4 for BR and 8 dS m<sup>-1</sup> for CMO and CMA (Fig. 1b).

**P uptake under salt stress:** Elemental compositions of leaves at the beginning of flowering stage in control treatment were given in Table 2. Comparison of these values to literature values (Alpaslan *et al.*, 2005) and visual observation showed no nutritional disorder. Therefore, any changes regarding P uptake by plants under increasing salinity may not directly related to any nutrient deficiency in the growing media.

The interaction between salt concentration of irrigation water and P content of plant leaves were shown in Fig. 2. Data showed that the interaction between salinity and phosphorous uptake was highly dependent on plant species (or cultivar) and level of salinity as constant amount of P supplied. The response of various species was significantly different to salt stress: i) P content did not change significantly but only small fluctuations (i.e., CMO), ii) stayed nearly constant up to 4 or 8 dS m<sup>-1</sup> then increased (i.e., CMA and FRG), iii) decreased after an initial increase at 4 dS m<sup>-1</sup> (i.e., LCY) and iv) increased irregularly (i.e., CT, SKP). FRG and BR were able to control P uptake fairly good up to 8 dS m<sup>-1</sup> but with increasing salinity P content of them was 2 or three fold higher than that of the control (Fig. 2).

## DISCUSSION

**Growth performance:** The general effect of salinity was to reduce the growth rate resulting in smaller leaves, shorter stature and sometimes fewer leaves especially EC above 8 dS m<sup>-1</sup>. The growing performance of gourds under salinity stress was dependent on species and cultivars. Similarly, Shannon and Grieve (1999) after reviewing quantitative information on crop salt tolerance exists for over 130 crop species concluded that the degree to which growth is reduced by salinity differs greatly with species and to a lesser extent with varieties within a species. On the other hand, plant response to salinity stress is strongly related to environmental conditions including climatic parameters (Shannon *et al.*, 1994) and growing media (Grattan and Grieve, 1999) and composition of saline solution in relation to ionic toxicities or nutritional deficiencies. Relative salt tolerance of many agricultural species regarding the decrease in dry matter production under saline condition has been associated with an increase in P uptake (Bernstein *et al.*, 1974; Cerda *et al.*, 1977; Rogers *et al.*, 2003). Here in this study a dramatic increase in P uptake were determined under increasing salinity stress that was accompanied by a dramatic decrease in both shoot and root growth. In contrast, Champagnol (1979) reviewed 17 publications and concluded that P, added to saline soils probably having P deficiency, increased crop growth and yield in 34 of the 37 crops studied, but this did not necessarily increase crop salt tolerance. These studies concluded that P addition had no effect, but correcting P deficiency, on salt tolerance of horticultural crops such as carrot, maize, sugar beet, *Beta vulgaris* L. and tomato, as salinity increased from low, to moderate, to high levels, respectively.

**P uptake under salt stress:** The capacity of roots for Pi uptake is regulated over a wide range by the P status of the plant (Jungk *et al.*, 1990). Multiple transporters in the plasma membrane (Schachtman *et al.*, 1998) are strongly regulated by the external Pi concentration (Leggiewie *et al.*, 1997). The availability of Pi in growing media dominates either low affinity or high affinity Pi uptake by plants (Navarro *et al.*, 2001; Furihata *et al.*, 1992). Salinity increased the net uptake rate of Pi through the low affinity mechanism, although it decreased the affinity of the transporter for Pi in melon plants whereas there was a salinity-induced decrease in high affinity Pi uptake (Navarro *et al.*, 2001). They also observed Pi toxicity in some plants under saline conditions caused by salinity induced Pi uptake through the low affinity system. In this study, P uptake by most of the gourd species increased

since the amount of P in the growing media supported the low affinity Pi uptake under increasing salinity stress where absence of strong adsorption sites (i.e., Fe and Al oxides, clay minerals and carbonates) and organic media that increase the availability of P. Several studies conducted in solution cultures have shown similar results: P concentrations that are optimal in non-saline solutions may adversely affect growth or be toxic to corn, melon and possibly other agronomic crops grown under saline conditions (Cerda *et al.*, 1977; Navarro *et al.*, 2001; Nieman *et al.*, 1976; Roberts *et al.*, 1984). In these cases salinity by some mechanism causes the plant to lose control of phosphate uptake (Roberts *et al.*, 1984) and transport from storage parts to other parts. Such increase in P uptake was related to different mechanisms: i) alkalization of the cytosol in root tip cells that cause an increase in P uptake (Martinez and Lauchli, 1994), ii) salinity induced changes in the H<sup>+</sup> electrochemical gradient across the plasma membrane that inhibits translocation of P from storage compartments to other parts of plants (Navarro *et al.*, 2001) and iii) for Pi uptake in plants, a co-transport with H<sup>+</sup> was proposed (Ullrich-Eberius *et al.*, 1984) with a stoichiometry of 1 or 2 H<sup>+</sup>/Pi (Mistrik and Ullrich, 1996) which may change the electrochemical gradient of plasma membrane and thus excessive Pi uptake may result. In contrast, salinity decreases the concentration of P in plant tissue (Sharpley *et al.*, 1992) for most cases, but the results of some studies indicate salinity either increased or had no effect on Pi uptake in soil environment. Because Pi availability in soil solution is reduced by both ionic strength and chemical reactions of P with soil components such as clay and carbonate minerals in saline soils (Hamad *et al.*, 1992; Millero *et al.*, 2001).

P uptake and growth of gourds and watermelon were significantly increased by salt concentration of irrigation water. Salt tolerant species such as CMO and CMA have a tendency to keep constant P uptake under extreme salt stress. SKP, FRG and BR were also promising species as regarded their ability to control P uptake. Therefore such resistant species may be used as rootstock to watermelon to be cultivated under saline conditions. Although, LCY was able to control P uptake, it was ruled out because of extreme loss of growth performance, even worse than CT, under saline conditions.

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