Journal of Biological Research **7**: 99 – 104, 2007
J. Biol. Res. is available online at http://www.jbr.gr
Indexed in: CAS (Chemical Abstracts Service) and DOAJ (Directory of Open Access Journals)

Effects of NaCl and Fe-EDDHA concentration on salt toxicity and chemical composition of gardenia (*Gardenia jasminoides* Ellis) plants

EFROSSINI AVRAMAKI[1*], CHRISTOS CHATZISSAVVIDIS[2] and IOANNIS PAPADAKIS[1]

[1] *Department of Horticulture, School of Agriculture, Aristotle University, 54 124 Thessaloniki, Greece*
[2] *Department of Agricultural Development, Democritus University of Thrace, 68 200 Orestiada, Greece*

Received: 18 April 2006 Accepted after revision: 29 August 2006

Young gardenia (*Gardenia jasminoides* Ellis) plants rooted under a fog system were grown in black plastic bags containing a sand/perlite (1:1) mixture. The plants were irrigated with Hoagland No2 nutrient solution modified to contain three Fe concentrations (0.5, 1 and 2 mg l^{-1}) in the form of Fe-EDDHA and four concentrations of NaCl (0, 10, 20 and 40 mM). After three months, severe toxicity symptoms were observed on the older leaves (chlorosis of tips and margins) mainly of the plants treated with 40 mM NaCl. Salinity had little effect on leaf P, whereas P concentration of roots increased in the treatments containing 20 or 40 mM NaCl plus 0.5 mg l^{-1} Fe. Generally, K and Ca concentrations of leaves and roots were not affected by the increase of NaCl concentration in the nutrient solution. In the roots, the lowest Mg concentration was observed in the treatments containing 2 mg l^{-1} Fe, whereas in the leaves, no significant differences were recorded. Regarding Mn concentration, it was not affected in the leaves but it increased in the roots of the treatments containing 20 and 40 mM NaCl plus 0.5 mg l^{-1} Fe. Finally, Fe concentration was increased in the roots of the plants treated with 0.5 mg l^{-1} Fe plus 20 or 40 mM NaCl. Concerning Na concentration, generally, it was increased in the leaves and decreased in the roots of the treatments containing high NaCl plus low or medium Fe concentration.

Key words: gardenia, iron, salinity.

INTRODUCTION

Iron chlorosis of plants is very common on calcareous or alkaline soils or in potting media. Although Fe is abundant in all soils, it is not readily available to all plant species grown under conditions of Fe deficiency. Iron chlorosis affects both growth/flowering and quality of gardenia plants. About 25% of the world population lives in arid areas where drought and salt accumulation are major limiting factors. Such conditions reduce Fe absorption. Under these conditions the quality of irrigation water is deteriorated and water content in salts increases affecting the growth of gardenia plants and leading to salt toxicity symptoms.

It is well known that soil salinity causes injury symptoms to plants. The main salts involved are chlorides, sulfates and nitrates. The possible factors contributing to salinization include the supply of animal manure or compost with a high salt content, the excessive application of chemical fertilizers, the use of brackish water for irrigation, the high water table, and the exposure to salt spray near the sea. The first symptoms of salinity are small, chlorotic or bluish-green leaves and stems with short internodes. The advanced symptoms of salinity in plants include browning and necrosis of leaf edges or other leaf tissues.

Salinity tolerance of ornamental plants on gradually increased salt concentration in nutrient solution is an important factor, particularly for planning of a fertilizer program and for the evaluation of the suitability of the irrigation water. Usually, chlorosis is initially observed and later necrosis on the tips and mar-

* Corresponding author: tel.: +30 25520 27960, fax: +30 25520 22229, e-mail: glimper@otenet.gr

gins of the oldest leaves of ornamental plants. This phenomenon is due to salt accumulation in the soil solution inducing severe problems to the marketable quality of the ornamental plants. Many surveys have been conducted concerning the effects of salinity on ornamental plants, e.g. poinsettias and pinks (Lunt *et al*., 1957).

Some species (halophytes) respond to salinity in a characteristic way; their growth is promoted by high NaCl (El Haddad & O'Leary, 1994). However, most glycophytes are susceptible to soil salinity. Gardenia is a relatively sensitive species to salinity and its susceptibility has not been studied adequately (Lunt *et al*., 1957).

There are suggestions in the literature (Dahiya & Singh, 1976) stating that the unfavorable effect of salinity becomes limited by Fe application in the nutrient solution. Therefore, this paper attempts to briefly review and to suggest possible means of solving the persistence of gardenia nutritional problems. These are the combined effects of salinity (NaCl) with Fe chlorosis on the chemical composition of gardenia plants.

MATERIALS AND METHODS

Gardenia (*Gardenia jasminoides* Ellis) terminal leafy cuttings were rooted under a fog system, in a mixture of peat and perlite (1:1) for two months. The young plants were maintained for 45 days in the fog system to develop an adequate root system. The rooted plants were removed from the fog system and their roots were washed in tap water and distilled water in order to remove any adhering peat and perlite particles. Afterwards, the plants were grown in 2 l black plastic bags containing perlite and quartzitic sea sand (1:1), leached with distilled water to remove the salts.

The plants were irrigated with a modified half strength Hoagland No2 nutrient solution (Hoagland & Arnon, 1950) containing three Fe concentrations (0.5, 1 and 2 mg l^{-1}) in the form of Fe-EDDHA (6%) in combination with four NaCl concentrations (0, 10, 20 and 40 mM). Five plants (replicates) were used in each treatment and were maintained in a greenhouse for three months. At the termination of the experiment, the plants were divided into roots and leaves and were washed twice with tap water and once with deionized water. The samples (leaves and roots) were dried at 75 °C for 48 h, ground in a mill to pass a 20 mesh screen and ashed at 500-550 °C. Subsequently, the samples were analyzed for K, Ca, Mg, Fe, Mn, Zn and Na by atomic absorption spectroscopy. Means were compared using the Duncan multiple range test ($p \leq 0.05$).

RESULTS

At the end of the experiment, severe toxicity symptoms (chlorosis of tips and margins of the oldest leaves) were recorded in the leaves due to salinity. These symptoms were more intense in the treatments with the highest NaCl concentration (40 mM).

Leaf P concentration decreased in the treatment of 40 mM NaCl plus 1 mg l^{-1} Fe, whereas no significant differences were observed concerning K, Ca, Zn and Mn concentrations (Fig. 1). In the leaves, Mg concentration decreased only in the plants treated with a nutrient solution containing 40 mM NaCl plus 0.5 mg l^{-1} Fe (Fig. 1), whereas Fe concentration was reduced in the treatments containing 40 mM NaCl plus 1 mg l^{-1} Fe. However, Na concentration of leaves increased in the plants treated with a nutrient solution containing 40 mM NaCl plus 0.5 mg l^{-1} Fe, as well as 20 or 40 mM NaCl plus 1 mg l^{-1} Fe (Fig. 1).

In the roots, P concentration increased in the treatments containing 0.5 mg l^{-1} Fe plus 20 or 40 mM NaCl and 40 mM NaCl plus 1 mg l^{-1} Fe (Fig. 2). Leaf Fe had the lowest value with 40 mM NaCl plus 1 mg l^{-1} Fe. Concerning root K concentration, it increased only in the treatment containing 20 mM NaCl plus 0.5 mg l^{-1} Fe. In the roots of the plants treated with 2 mg l^{-1} plus 20 mM NaCl, Ca concentration increased. Concerning root Mg concentration, the lowest values were observed in the plants treated with 2 mg l^{-1} Fe. In all plants treated with 0.5 mg l^{-1} Fe plus 20 or 40 mM NaCl, root Fe concentration increased. Similarly, root Fe increased in the treatments of 40 mM NaCl plus 0.5 mg l^{-1} Fe. High NaCl concentrations (20 and 40 mM) combined with 0.5 mg l^{-1} Fe in the nutrient solution led to an increase of the Mn concentration in the roots. Root Zn concentration increased in the treatment of 40 mM NaCl plus 0.5 mg l^{-1} Fe. Finally, salinity reduced Na concentration in the roots of the plants treated with 0.5 mg l^{-1} Fe.

DISCUSSION

The observed symptoms in the leaves of gardenia plants were characteristic of Na toxicity. The susceptibility of gardenia plants to salinity is well known for many years (Lunt *et al*., 1957). Iron chlorosis of plants is especially prevalent in gardenia plants on calcare-

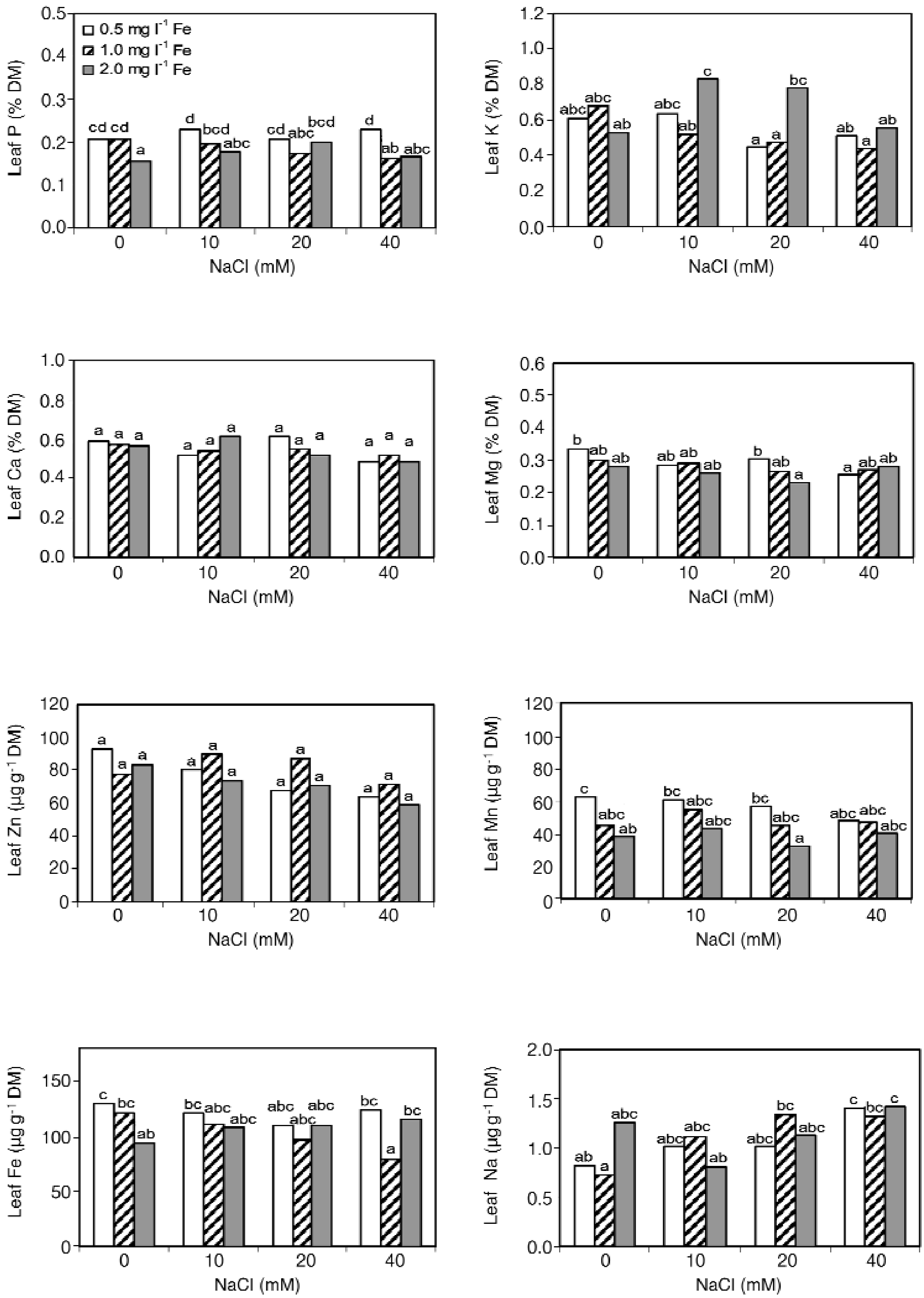

FIG. 1. Chemical composition of leaves at the end of the experiment. Means with the same letter in the same nutrient are not significantly different at $p \leq 0.05$ (Duncan multiple range test).

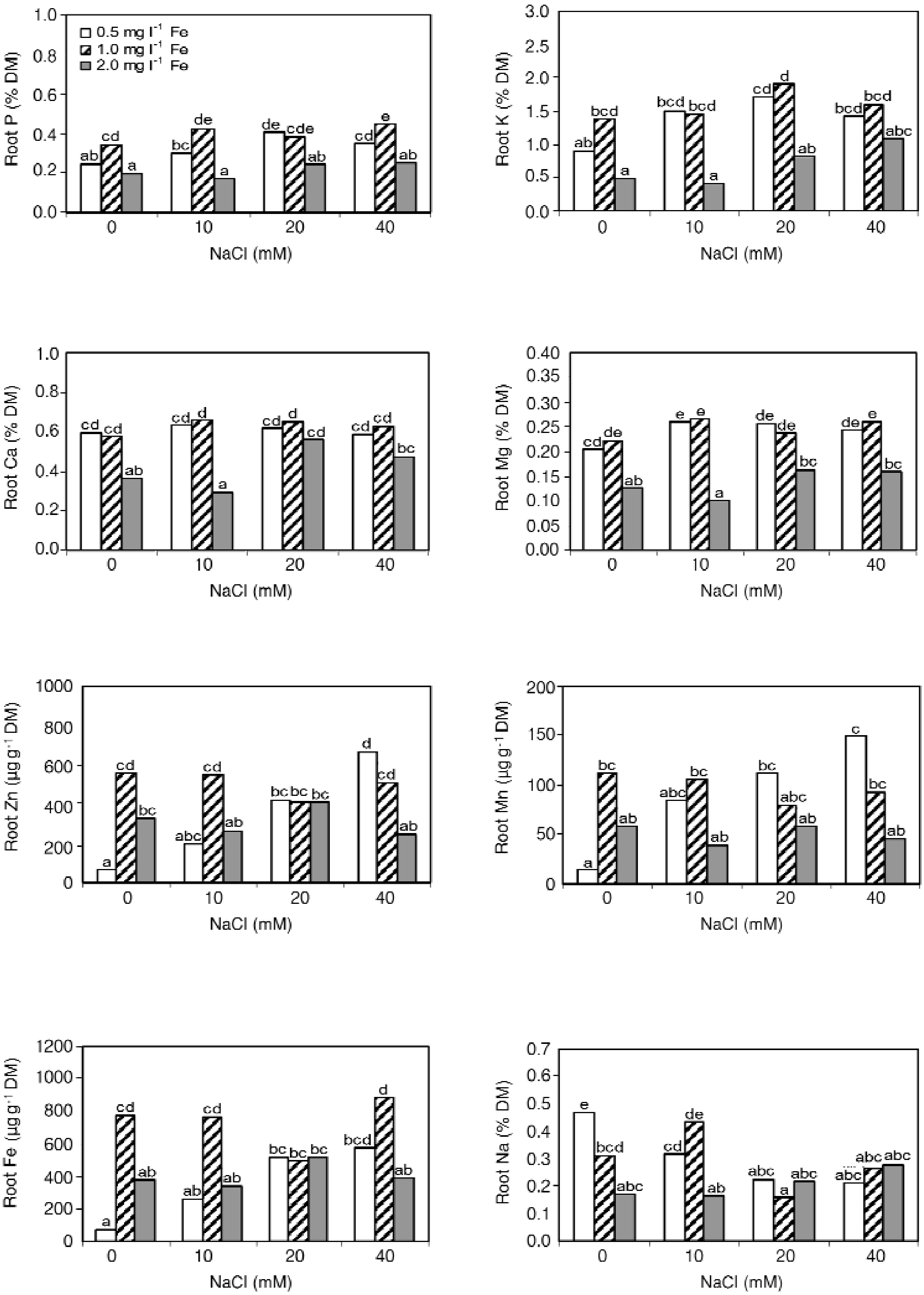

FIG. 2. Chemical composition of roots at the end of the experiment. Means with the same letter in the same nutrient are not significantly different at $p \leq 0.05$ (Duncan multiple range test).

ous or alkaline substrates and in substrates low in Fe. Direct evidence for this relationship is lacking, but it is believed that decreased root growth with increased substrate or irrigation solution salinity may be the reason. Those conditions which reduce root development and subsequent Fe uptake directly or indirectly may result in Fe chlorosis of Fe-inefficient gardenia plants growing in soils with marginal levels of available Fe.

The results of our study indicate that salinity has little effect on leaf P concentration. As reported in the literature, in most cases, salinity decreases P concentration in plant tissues (Sharpley *et al*., 1992) and this is related to growth conditions, plant species and cultivar (Grattan & Grieve, 1994). However, most of these studies have not been conducted in an inert substrate but in soils where Fe levels are difficult to be controlled. Phosphate availability is reduced in saline soils not only because of ion interaction but also because of P precipitation in the soil. Phosphate concentration in the solution is highly controlled by the absorption process and P precipitation with Ca minerals. However, in other studies, salinity increased tissue P concentration (Grattan & Grieve, 1994).

Phosphorus concentration in the roots increased in the treatments with high NaCl concentration plus low Fe concentration in the nutrient solution. On the contrary, Pakroo & Kashirad (1981) found similar results in sunflower plants treated with low NaCl concentrations. In the literature, it has been reported that many plants have high affinity and low affinity uptake systems for certain nutrients. High affinity systems are most likely active mechanisms requiring P, some form of energy input supplied either by ATP or by a proton electrochemical gradient (Maathius *et al*., 1996). Pre-treatment of *Chara* cells in the absence of P_i stimulated uptake of ^{32}P, but only when Na was present in the uptake solution. The Na sensitive component of P_i uptake can be fitted with Michaelis-Menten kinetics. The k_m for Na for the P stimulation was found to be about 0.2 mM (Reid *et al*., 1997). Pakroo & Kashirad (1981) found that Fe in the nutrient solution induced the absorption of Fe, Mn and Zn regardless of the NaCl level. This was not verified in our experiment with gardenia plants.

Although K concentration in the present work was not affected by salinity, in other reports dealing with the salinity effects on tomato and soya plants, a possible antagonism between Na and K led to a decline of the latter in the leaves (Maas & Hoffman, 1972). Many studies on a wide range of horticultural crops have shown that K concentration declined as Na salinity in the root media increased (Subbarao *et al*., 1990; Izzo *et al*., 1991; Graifenberg *et al*., 1995; Perez-Alfocea *et al*., 1996; Arshi *et al*., 2005). However, an opposite effect was recorded in the leaves of bean plants where an increase of NaCl concentration led to an increase of K concentration (Cachorro *et al*., 1993). In accordance to our results, Zekri & Parsons (1992) observed that salinity did not affect Ca levels in *Citrus* roots.

Concerning Mg, generally, its concentration in gardenia plants was not affected by salinity (NaCl) and this is in agreement with other authors who studied five vegetable species (Bernstein *et al*., 1974).

Manganese concentration of gardenia leaves was not affected by the increase of the NaCl concentration. However, in the roots treated with high NaCl (20 and 40 mM) and low Fe (0.5 mg l^{-1}), Mn concentration increased. Whereas many studies on horticultural crops indicated that salinity reduced Mn concentration in plant tissues (Alam *et al*., 1989; Izzo *et al*., 1991; Rahman *et al*., 1993), other reports indicated no inhibitory effects of salinity (Al-Harbi, 1995) or that salinity increased Mn concentration (Niazi & Ahmed, 1984).

In our experiment, the increase in root Fe concentration in the treatments containing high salt concentration, agrees with the results of other authors experimenting with pea (Dahiya & Singh, 1976), tomato, soyabean and squash (Maas & Hoffman, 1972).

A characteristic effect of the increasing salinity was a decrease of the Na accumulation in the roots, although other scientists observed an increase of the root Na concentration (Cordovilla *et al*., 1995). Studies have revealed that, under salt stress, Na^+ enters the plant cells via the K transport system. Therefore, modification of K^+ transport may result in a Na^+ influx decrease and hence, in the improvement of salt tolerance in gardenia plants (Katsuhara, 1997).

REFERENCES

Alam SM, Naqvi SSM, Azmi AR, 1989. Effect of salt stress on growth of tomato. *Pakistan journal of scientific and industrial research*, 32: 110-113.

Al-Harbi AR, 1995. Growth and nutrient composition of tomato and cucumber seedlings as affected by sodium chloride salinity and supplemental calcium. *Journal of plant nutrition*, 18: 1403-1416.

Arshi A, Abdin MZ, Iqbal M, 2005. Ameliorative effects of $CaCl_2$ on growth, ionic relations, and proline content of senna under salinity stress. *Journal of plant nutrition*, 28: 101-125.

Bernstein L, Francois LE, Clark RA, 1974. Intensive effects of salinity and fertility on yields of grains and vegetables. *Agronomy journal*, 66: 412-421.

Cachorro P, Ortiz A, Cetda A, 1993. Growth, water relations and solute composition of *Phaseolus vulgaris* L. under saline conditions. *Plant science*, 95: 23-29.

Cordovilla MP, Ocana A, Ligero F, Lluch C, 1995. Growth and macronutrient contents of faba bean plants: effects of salinity and nitrate nutrition. *Journal of plant nutrition*, 18: 1611-1628.

Dahiya SS, Singh M, 1976. Effect of salinity, alkalinity and iron application on the availability of iron, manganese, phosphorus and sodium in pea (*Pisum sativum* L.) crop. *Plant and soil*, 44: 697-702.

El Haddad ESHM, O'Leary JW, 1994. Effect of salinity and K/Na ratio of irrigation water on growth and solute content of *Atriplex amnicola* and *Sorghum bicolour*. *Irrigation science*, 14: 127-133.

Graifenberg A, Giustiniani L, Temperini O, Lipucci di Paola M, 1995. Allocation of Na, Cl, K and Ca within plant tissues in globe artichoke (*Cynara scolimus* L.) under saline-sodic conditions. *Scientia horticulturae*, 63: 1-10.

Grattan SR, Grieve CM, 1994. Mineral nutrient acquisition and response by plants grown in saline environments. In: Pessarakli M, ed. *Handbook of plant and crop stress*. Marcel Dekker, New York: 203-226.

Hoagland DR, Arnon DI, 1950. *The water culture method for growing plants without soil*. California Agriculture Experimental Station, Circular 347.

Izzo R, Navari-Izzo F, Quartacci MF, 1991. Growth and mineral absorption in maize seedlings as affected by increasing NaCl concentrations. *Journal of plant nutrition*, 14: 687-699.

Katsuhara M, 1997. Molecular aspects of potassium and water transport, and their bearing under salt stress. In: Ando T, Fujita K, Mae T, Matsumoto H, Mori S, Sekiya J, eds. *Plant nutrition for sustainable food production and environment*. Kluwer Academic Publishers, Japan: 201-202.

Lunt OR, Kohl HC, Kofranek AM, 1957. Tolerance of azaleas and gardenias to salinity conditions and boron. *Proceedings of the american society for horticultural science*, 69: 543-548.

Maas EV, Hoffman GJ, 1972. Influence of salinity on Fe, Mn, and Zn uptake by plants. *Agronomy journal*, 64: 793-795.

Maathius FJM, Verlin D, Smith FA, Sanders D, Fernandez JA, Walker NA, 1996. The physiological relevance of Na^+-coupled K^+-transport. *Plant physiology*, 112: 1609-1616.

Niazi BH, Ahmed T, 1984. Effect of sodium chloride and zinc on the growth of tomato. Uptake of ions. *Geobios*, 11: 155-160.

Pakroo N, Kashirad A, 1981. The effect of salinity and iron application on growth and mineral uptake of sunflower. *Journal of plant nutrition*, 4: 45-56.

Perez-Alfocea F, Balibrea ME, Santa Cruz A, Estan MT, 1996. Agronomical and physiological characterization of salinity tolerance in a commercial tomato hybrid. *Plant and soil*, 180: 251-257.

Rahman S, Vance GF, Munn LC, 1993. Salinity induced effects on the nutrient status of soil, corn leaves and kernels. *Communications in soil science and plant analysis*, 24: 2251-2269.

Reid RJ, Mimura T, Smith FA, 1997. A high affinity Na-dependent phosphate uptake induced by P starvation in *Chara*. In: Ando T, Fujita K, Mae T, Matsumoto H, Mori S, Sekiya J, eds. *Plant nutrition for sustainable food production and environment*. Kluwer Academic Publishers, Dordrecht: 137-138.

Sharpley AN, Meisinger JJ, Power JF, Suarez DL, 1992. Root extraction of nutrients associated with long-term soil management. In: Stewart B, ed. *Advances in soil science*. Springer, New York: 151-217.

Subbarao GV, Johansen C, Jana MK, Kumar Rao JVDK, 1990. Effects of the sodium/calcium ratio in modifying salinity response of pigeon pea (*Cajanus cajan*). *Journal of plant physiology*, 136: 339-443.

Zekri M, Parsons LR, 1992. Salinity tolerance of citrus rootstocks: Effect of salt on root and leaf mineral concentrations. *Plant and soil*, 147: 171-181.