Pak. J. Bot., 39(3): 769-776, 2007.

IMPROVING GROWTH AND YIELD OF SUNFLOWER (*HELIANTHUS ANNUUS* L.) BY FOLIAR APPLICATION OF POTASSIUM HYDROXIDE (KOH) UNDER SALT STRESS

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Abstract

An experiment was conducted to assess whether KOH applied as a foliar spray could mitigate the adverse effects of salt stress on plant growth and yield of sunflower plants. For this purpose, KOH @ 0, 0.5, 1.0, 1.5 and 2.0% was applied as a foliar spray to salt stressed and non-stressed sunflower plants. Foliar spray of KOH increased the growth and yield under non-stress and salt stressed conditions. Increasing levels of KOH increased leaf K^+. Although foliarly applied KOH had growth promoting effects, it did not change nutrient status except leaf K. Thus, foliar application of K as KOH improved growth and yield of sunflower plants by improving K^+/Na^+ ratio.

Introduction

Salinity exerts a number of adverse effects on plants including osmotic effects, ion toxicity and nutritional imbalance resulting in reduced growth and yield (Ashraf, 2004; Munns, 2005). High amounts of Na^+ in the growth medium perturb the nutrient uptake in plants (Marschner, 1995; Grattan & Grieve, 1999; Ashraf, 2004), eg., green bean (Pessarakli, 1991), sunflower (Ashraf & Sultana, 2000), tomato (Flores *et al*., 2000), and *Bruguiera parviflora* (Parida & Das, 2004). It is suggested that high external Na^+ inhibits the uptake of other nutrients particularly K, by interfering with the transport mechanisms at the root plasma membrane such as K^+-selective ion channels (Tester & Davenport, 2003). The capacity of plants to counterbalance salt stress depends largely on the status of their K nutrition because that latter plays a vital role in many cell processes; including enzymatic activation, cell turgor, regulation of stomatal movement and maintenance of osmotic homeostasis (Shabala *et al*., 2003).

Different researchers have shown that the deleterious effects associated with reduced uptake and translocation of K^+ by plants grown in high Na^+ were alleviated by the addition of K^+ to the growth medium, eg., in tomato (Satti & Lopez, 1994), maize (Botella *et al.*, 1997), and bean and sunflower (Benlloch *et al*., 1994). However, K remained at relatively low concentration in soil solution besides the addition of K salts in the soil (Grattan & Grieve, 1999). Thus, it is very difficult to completely correct Na-induced K deficiencies by the addition of K fertilizers in soil. Alternatively, foliar applied macro-nutrient therapy has proved to be useful in mitigating the nutritional deficiency eg., in cotton (Howard, 1993; Howard *et al*., 1998), avocado (Sing & McNeil, 1992), and 'French' prune trees (Southwick *et al.*, 1996). Different K sources and doses are being used as a foliar spray. However, each K source has its own advantages and disadvantages, and shows variable responses on different crop plants. For example, K_2CO_3 was found to be effective in potato as it is less toxic to leaf tissue and is taken up by the leaf more efficiently (Patterson, 2005). Mullins & Burmester (1995) also reported an increased lint yield in cotton by foliar application of K, but with no difference among different K sources, KNO_3, K_2SO_4, $K_2S_2O_3$, and KCl. In view of economic importance of sunflower as oil-seed crop, an experiment was conducted to test whether foliar application of Potassium hydroxide might alleviate the adverse effects of salt stress on sunflower plants by enhancing leaf K.

Materials and Methods

A pot experiment was conducted during spring 2005 in a naturally lit wire-house in the Botanic Gardens, Department of Botany, University of Agriculture, Faisalabad, Pakistan (latitude 31°30 N, longitude 73°10 E and altitude 213 m). Achenes of sunflower (*Helianthus annuus* L cv. SF -187, Monsanto, USA) were obtained from the Regional Office of Pakistan Seed Council, Faisalabad, Pakistan. During the experiment, day and night temperatures were 30.6 ± 5.1 ^{o}C, and 18.3 ± 7.6 ^{o}C, respectively, relative humidity (RH) 35.9 ± 6.5, and the day length varied from 8 to 11. Achenes of sunflower were surface sterilized in 5% Sodium hypochlorite solution for 10 minutes before further experimentation. Ten sunflower achenes were directly sown in each plastic pot of 28 cm diameter, but after germination, seedlings were thinned to four of almost uniform size. Each pot contained 12.5 kg of well washed sand. The experiment was arranged in a completely randomized design with four replicates. All pots were irrigated with full strength Hoagland's nutrient solution for 18 days after which NaCl treatments in Hoagland's nutrient solution were begun. The NaCl concentrations used were 0 or 150 m*M* in full strength Hoagland's nutrient solution. Salt solution was applied in aliquots of 50 mM every day. Two liters of treatment solution were applied to each pot at weekly intervals, however, moisture content of the sand was maintained daily by adding 200 ml distilled water to each pot. Different concentrations of K as KOH [(NS (No spray), WS (spray of water+ 0.1% Tween 20 solution), 0.5, 1.0, 1.5 and 2.0% K in 0.1% Tween 20 solution)] applied foliarly two times to non-stressed and salt stressed sunflower plants. First foliar application of K was done one week after the commencement of salt treatment. The second foliar application was done one week after the first application. Each KOH treatment or blank solution was prepared in 0.1% Tween-20 solution and its pH was maintained at 6.5 to ensure the maximum penetration of salt into the leaf tissue and to avoid the leaf injury.

Growth and yield: Four weeks after the commencement of salt stress, two plants from each pot were harvested and used for the estimation of growth and mineral contents of plants, while the remaining two plants were used for the estimation of yield and yield components. Plant roots were carefully removed from the sand and washed in cold $LiNO_3$ solution isotonic with the corresponding treatment in which plants were growing. One mM of $Ca(NO_3)_2.4H_2O$ solution was added to $LiNO_3$ solution to maintain membrane integrity. Shoots and roots were weighed for fresh weights and plant material was oven-dried at 65 ^{o}C for one week for recording dry weights. At maturity, heads of sunflower were removed from plants and data for number of achenes per capitulum, 100 achenes weight, and achene yield/plant were recorded.

Inorganic elements: For the determination of N, P, K, Ca, Mg and Na, the dried, ground leaf and root material (0.1 g) was digested with sulphuric acid and Hydrogen peroxide

(Merck) and Na, K, and Ca in the digests were determined with a flame photometer (Jenway, PFP-7). Mg^{2+} was determined on an atomic absorption spectrophotometer (Perkin Elmer Analyst 300, USA). Nitrogen was estimated by micro-Kjeldhal's method (Bremner, 1975). Phosphorus (P) was determined spectrophotometrically following Jackson (1962). Leaf and root samples (100 mg) were ground and extracted in distilled water and Cl^- content was determined with a chloride analyzer (Model 926, Sherwood Scientific Ltd., Cambridge, UK).

Experimental design and statistical analysis: The experiments were set up in a completely randomized design (CRD) with four replicates. Analysis of variance of all parameters was computed using the COSTAT computer package (CoHort Software Inc., Berkeley, USA). The least significance difference between the mean values was calculated following Snedecor & Cochran (1980). The Duncan's New Multiple Range test (DMRT) at 5% level of probability was also used to test the difference among mean values.

Results

The data for fresh and dry weights of shoots and roots of sunflower are presented in Fig 1. Salt stress of the growth medium caused a significant ($p<0.001$) reduction in shoot and root fresh and dry weights of sunflower. Application of varying levels of Potassium nitrate (KOH) improved the shoot fresh and dry weights of sunflower under both control and saline conditions. However, a highest increase in shoot fresh and dry weight of control and stressed plants was observed when 1% K of (KOH) applied as a foliar spray. Further increase in the level of K application did not further improve shoot fresh and dry weights of non-salinized or salinized plants. But application of different levels of K from KOH did not cause an improvement in root fresh and dry weights of non-salinized and salinized plants, however, a small increase in fresh weight was observed in salinized plants, when 1% K as KOH was applied as foliar spray.

Yield and yield components such as achene yield, number of achenes, and 100 achene weights were significantly reduced due to imposition of salt stress However, application of different levels of K from KOH salt improved all these yield attributes of both non-stressed and salt stressed plants (Fig. 2). Maximum increase in these yield attributes were observed at 1% K level in non stress plant, while in stress plant maximum improvement was achieved at 0.5% K level.

Leaf and root N, P and K^+ were significantly reduced due to NaCl salt in the rooting medium (Fig. 3). Application of varying levels of K increased root K in non stressed and stressed plant and leaf P in salt stressed plants, while 1.0 % K level generally caused a maximal increase in leaf K of non-stressed and stressed plants. Salt stress reduced leaf and root Ca^{2+} and Mg^{2+}. However, foliar application of different doses of K did not alter the accumulation of Ca^{2+} and Mg^{2+} in the leaves and roots, except in salt stressed plants where 1.0% KOH caused an increase in leaf Ca^{2+}. Concentrations of Na^+ and Cl^- in shoots and roots were significantly increased under salt stress (Fig. 4). Application of different levels of KOH significantly reduced Na^+ in the leaves, however, concentration of Na^+ in the roots, or those of Cl^- in the leaves and roots remained unaltered under both non-saline and saline conditions. K^+/Na^+ ratios were consistently increased in salt stressed plants with an increase in K level from KOH.

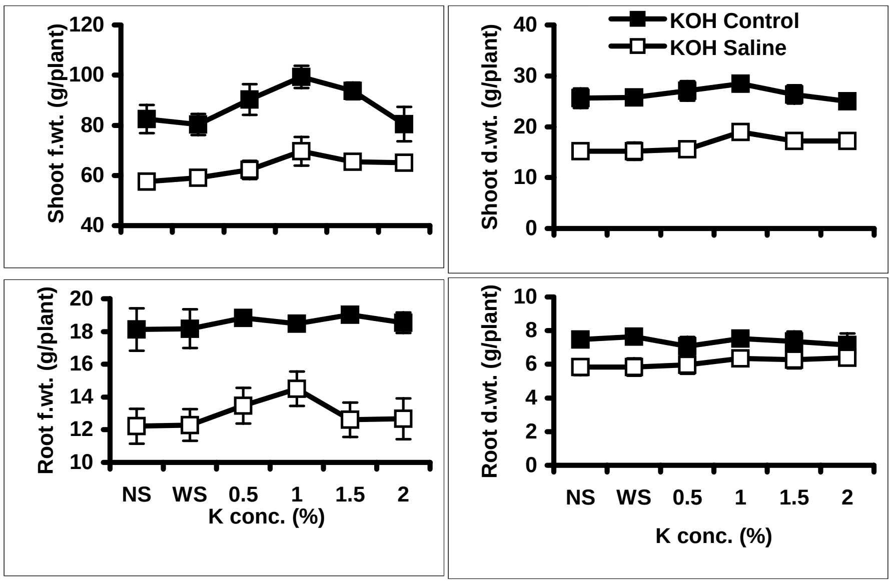

Fig. 1. Shoot and root fresh and dry weights of sunflower (*Helianthus annuus*) when KOH was applied as a foliar spray to 18-day old plants subjected to normal or saline conditions.

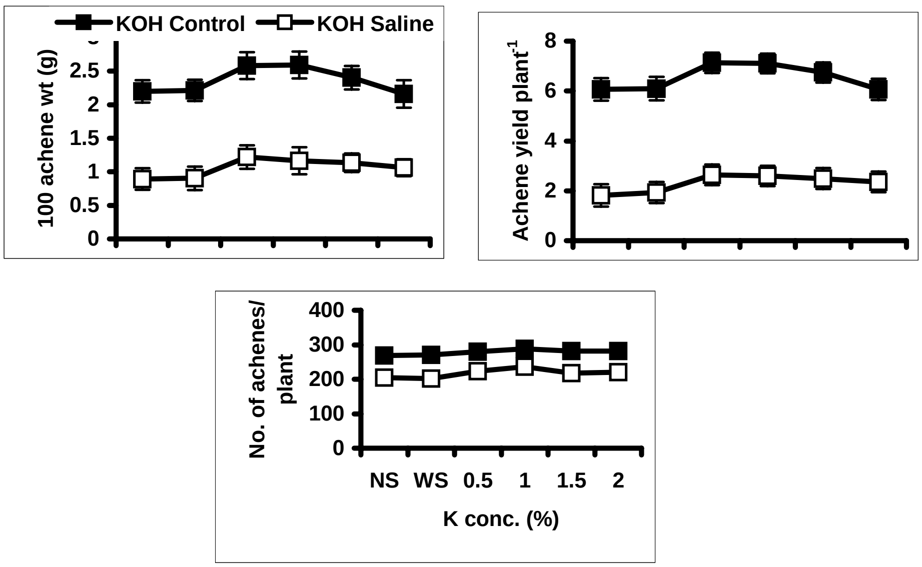

Fig. 2. Achene yield, No of achene per plant and 100 achene weight of sunflower (*Helianthus annuus*) when KOH was applied as a foliar spray to 18-day old plants subjected to normal or saline conditions.

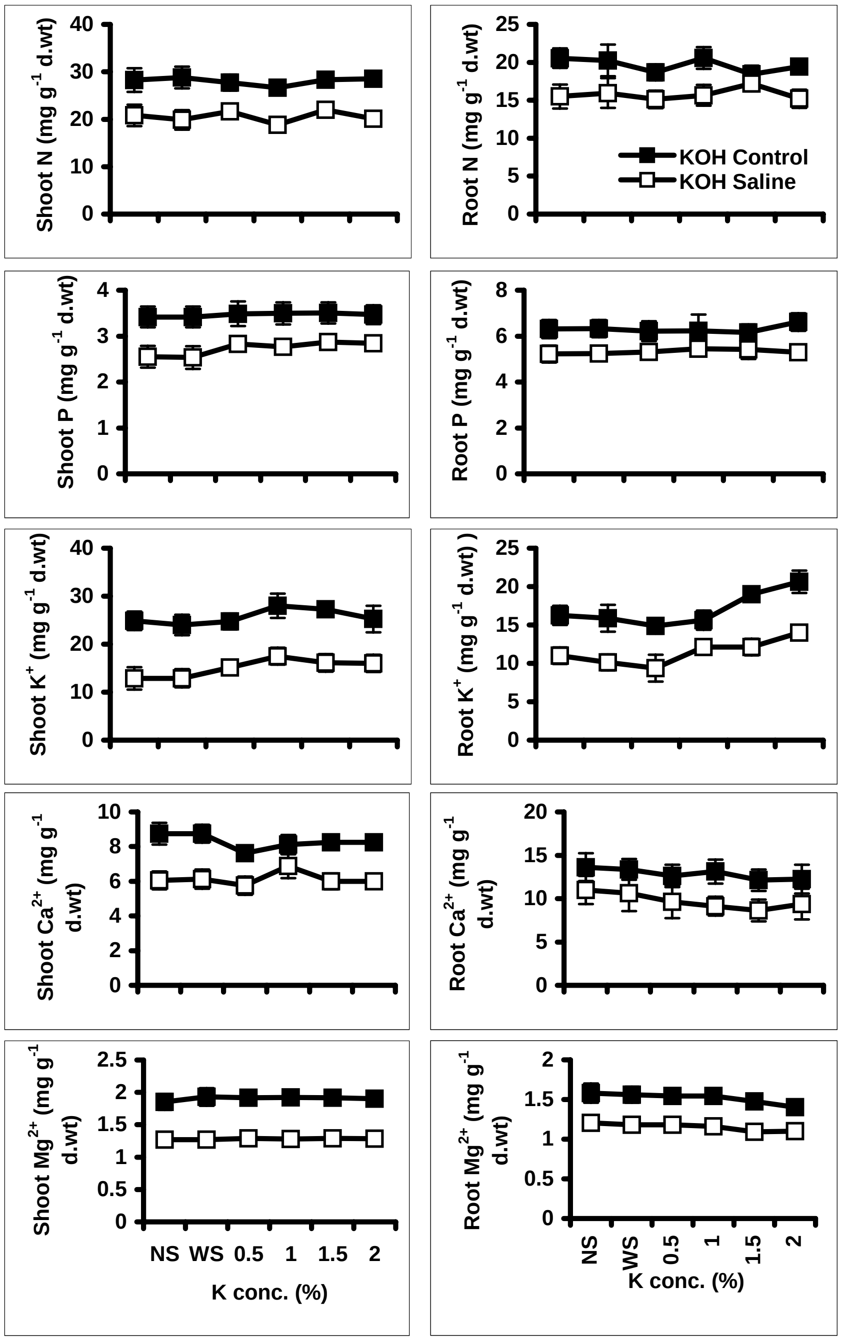

Fig. 3. N, P, K, Ca, and Mg concentrations of leaves and roots of sunflower (*Helianthus annuus*) when KOH were applied as a foliar spray to 18-day old plants subjected to normal or saline conditions.

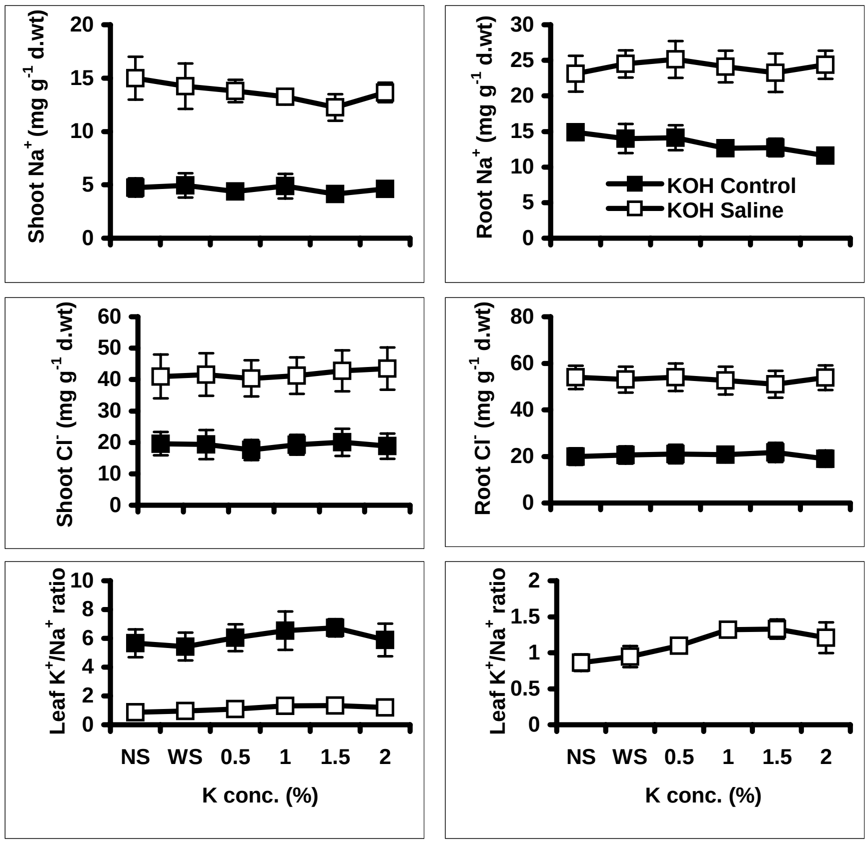

Fig. 4. Na^+ and Cl^- of leaves and roots, and leaf K^+/Na^+ ratio of sunflower (*Helianthus annuus*) when KOH was applied as a foliar spray to 18-day old plants subjected to normal or saline conditions.

Discussions

The growth medium salinity caused a marked reduction in growth and yield of sunflower. However, application of potassium as Potassium hydroxide improved the growth and yield of sunflower plants under both non-saline and saline conditions. These results can be correlated to the findings in which it has been observed that exogenous application of Potassium ameliorated the adverse effects of salinity and improved the growth attributes in different crop plants eg., strawberry (Kaya *et al.,* 2001a), and cucumber and pepper (Kaya *et al.,* 2003). Similarly in *Lagenaria siceraria* Ahmad & Jabeen (2005) reported that foliar application of Potassium nitrate counteracted the salt-induced growth inhibition in rice plants. However, in the present study 1% KOH was found to be effective in alleviating the adverse effects of salt stress on sunflower plants.

Maintenance of sufficient amount of Potassium is essential for plant growth under normal or saline environment. In the present study, foliar application of varying levels of K increased the tissue K contents of non-stressed and salt stressed plants. However, application of higher concentration of K caused leaf injuries or leaf burning with a subsequent reduction in accumulation of K in the leaves. Such reduction in nutrient absorption through leaves may have been due to destruction of ectodesmata structures (Marschner, 1995). This view is further supported by Weinbaum (1988) who reported that leaf burning, a common problem due to foliar spray with high concentration, can be overcome by using low salt index fertilizers (i.e. those free of Na and Cl) containing low K and proper adjuvant. Salt-induced reduction in leaf or root K was ameliorated by varying levels of leaf-applied K. These results are in agreement with those reported in other crops eg., cotton (Coker *et al*., 2000), strawberry (Kaya *et al*., 2001a), spinach (Kaya *et al*., 2001b), cucumber and pepper (Kaya *et al*., 2003).

Results for ion concentrations show that salt stress increased the accumulation of Na^+ and Cl^- with a decrease in N, P, K^+, Ca^{2+} and Mg^{2+} in salt stressed sunflower plants. These findings are generally in agreement with the view that plants growing under saline conditions suffer ionic imbalance, nutrient deficiency and specific ion toxicity (Ashraf, 1994; 2004; Munns, 2002; 2005). However, KOH had a little or no effect on leaf or root Na^+, Cl^-, Ca^{2+}, and Mg^{2+}. Application of K enhanced leaf K^+, with a concomitant decrease in leaf Na^+ which resulted in increased K^+/Na^+ ratio of salt stressed plants (Fig 4). Thus foliar application of K might have promoted uptake of K^+ and reduced that of Na^+. However, the detailed mechanism how foliar applied K^+ modulated Na^+ and K^+ transport activities in order to establish ionic homeostasis needs to be elucidated.

In conclusion, foliarly applied K as KOH caused an increase in leaf K. Higher leaf K^+ reduced Na^+ translocation from roots to shoots, which resulted in improved growth and yield.

References

Ahmad, R. and R Jabeen. 2005. Foliar spray of mineral elements antagonistic to sodium -a technique to induce salt tolerance in plants growing under saline conditions. *Pak J. Bot*., 37(4): 913-920.

Ashraf, M. 1994. Breeding for salinity tolerance in plants. *Crit. Rev. Plant Sci*., 13: 17-42.

Ashraf, M. 2004. Some important physiological selection criteria for salt tolerance in plants. *Flora*, 199: 361-376.

Ashraf, M. and R. Sultana. 2000. Combination effect of NaCl salinity and N-form on mineral composition of sunflower plants. *Biol. Plant*., 43: 615-619.

Benlloch, M., M.A. Ojeda, J. Ramos and A. Rodriguez-Navarro. 1994. Salt sensitivity and low discrimination between potassium and sodium in bean plants. *Plant Soil*, 166: 117-123.

Botella, M.A., V. Martinez, J. Pardines and A. CerdaÂ. 1997. Salinity induced potassium deficiency in maize plants. *J. Plant Physiol*., 150: 200-205.

Bremner, J.M. 1975. Total nitrogen and inorganic form of nitrogen. In: *Methods of Soil Analysis*, (Ed.): C.A. Black. Am. Soc. Agron. Madison, Wisconsin, pp. 1149-1237.

Coker, D.L., D.M. Oosterhuis, P. Dugger and D. Richter. 2000. Water deficit and K partitioning in cotton 2000 *Proc. Beltwide Cotton Conference*, San Antonio, USA, 4-8 January: Vol. 1, pp. 634-636.

Flores, P., M.A. Botella, V. Martinez and A. Cerda. 2000. Ionic and osmotic effects on nitrate reductase activity in tomato seedlings. *J. Plant Physiol*., 156: 552-557.

Grattan, S.R. and C.M. Grieve. 1999. Mineral nutrient acquisition and response of plants grown in saline environments. In: *Handbook of Plant and Crop Stress*. (Ed.): M. Pessarakli. Marcel Dekker Press Inc., New York, pp. 203-229.

Hoagland, D.R. and D.I. Arnon. 1950. *The water culture method for growing plant without soil*. California Agri. Exp. Sta. Cir. No. 347. University of California Berkley Press, CA., pp: 347.

Howard, D.D. 1993. Foliar fertilization of cotton as affected by surfactants and foliar solution pH. pp. 77-90. In: *Foliar fertilization of soybeans and cotton*. (Ed.): L.S. Murphy. PPI/FAR Spec. Publ. 1993-1. Potash & Phosphate Inst. and Foundation for Agronomic Res., Norcross, GA.

Howard, D.D., C.O. Gwathmey and C.E. Sams. 1998. Foliar feeding of cotton: Potassium sources, potassium solution buffering, and boron. *J. Agron*., 90: 740-746.

Jackson, M.L. 1962. *Soil chemical analysis*. Contable Co. Ltd. London.

Kaya, C., B.E. Ak and D. Higgs 2003. Response of salt stressed strawberry plants to supplementary calcium nitrate and/or potassium nitrate. *J. Plant Nutr*., 26(3): 543-560.

Kaya, C., H. Kirnak and D. Higgs. 2001a. The effects of supplementary potassium and phosphoruson physiological development and mineral nutrition of cucumber and pepper cultivarsgrown at high salinity (NaCl). *J. Plant Nutr*., 24(9): 285-294.

Kaya, C., H. Kirnak and D. Higgs. 2001b. Enhancement of growth and normal growth parameters by foliar application of potassium and phosphorus on tomato cultivars grown at high (NaCl) salinity. *J. Plant Nutr*., 24(2): 357–367.

Marschner, H. 1995. *Mineral Nutrition of Higher Plants*. Academic Press, London, pp. 889.

Mullins, G.L. and C.H. Burmester. 1995. Response of cotton to the source of foliar potassium. p. 1313-1315. In: (Ed.): D.A. Richter. 4. Response to foliar K. *Proc. Beltwide Cotton Conf*., San Antonio, TX. 4–7 Jan. 1995. Natl. Cotton Council of America, Memphis, TN.

Munns, R. 2002. Comparative physiology of salt and water stress. *Plant Cell Environ*., 25: 239-250.

Munns, R. 2005. Genes and salt tolerance: bringing them together. *New Phytol*., 167: 645-663.

Parida, A.K. and A.B. Das. 2004. Effects of NaCl stress on nitrogen and phosphorus metabolism in a true mangrove *Bruguiera parviflora* grown under hydroponic culture. *J. Plant Physiol*., 161: 921-928.

Pessarakli, M. 1991. Dry matter yield, nitrogen-15 absorption, and water uptake by green bean under sodium chloride stress. *Crop Sci*., 31: 1633-1640.

Petterson, R. and J.S. McDonald. 1994. Effects of nitrogen supply on the acclimation of photosynthesis to elevated CO_2. *Photosynthesis Res*., 39: 389-400.

Satti, S.M.E. and M. Lopez. 1994. Effect of increasing potassium levels for alleviating sodium chloride stress on the growth and yield of tomato. *Commun. Soil Sci. Plant Anal*., 25: 2807-2823.

Shabala, S. 2003. Regulation of potassium transport in leaves: from molecular to tissue level. *Ann. Bot*., 92: 627-634.

Sing, J. L. and R. J. McNeil. 1992. The Effectiveness of foliar potassium nitrate sprays on the 'Hass' Avocado *(Persea americana* Mill.) *Proc. of Second World Avocado Congress*, 1992 pp. 337-342.

Snedecor, G.W. and W.G. Cochran. 1980. *Statistical methods.* 7th edition, Iowa State University Press, Ames, Iowa.

Southwick, S.M., W. Olson, J. Yeager and K.G. Weis 1996. Optimum timing of potassium nitrate spray application to ‘french’ prune trees. *J. Amer. Soc. Hort. Sci*., 121: 326-333.

Tester, M. and R. Davenport. 2003. Na^+ tolerance and Na^+ transport in higher plants. *Ann. Bot*., 91: 503-50.

Weinbaum, S. A. 1988. Foliar nutrition of fruit trees. In: *Plant growth and leaf-applied chemicals*. (Ed.): P.M. Neumann. CRC Press, Boca Raton, Florida, pp 81-100.

(Received for publication 2 January 2007)