Journal of Ornamental Plants (Journal of Ornamental and Horticultural Plants)
Available online on: www.jornamental.com
ISSN (Print): 2251-6433
ISSN (Online): 2251-6441

Growth, Yield and Quality of *Rosa hybrida* L. as Influenced by NaCl Salinity

Iftikhar Ahmad[1*], Muhammad Aslam Khan[1], Muhammad Qasim[1], Rashid Ahmad[2] and Tauseef-Us-samad[1]
[1]Institute of Horticultural Sciences, University of Agriculture, Faisalabad-38040, Pakistan.
[2]Department of Crop Physiology, University of Agriculture, Faisalabad-38040, Pakistan.

Received: 25 March 2013 Accepted: 6 August 2013
*Corresponding author's email: iftikharahmadhashmi@gmail.com

Abstract

The effects of sodium chloride (NaCl) salinity (control; canal water with 0.4 dS m^{-1}), 2.5 dSm^{-1}, 5.0 dS m^{-1}, 7.5 dS m^{-1} and 10.0 dS m^{-1}, respectively) developed after 6 weeks of pruning (beginning of study) on plant growth, flowering and quality of three cut rose (*Rosa hybrida* L.) cultivars viz. 'Kardinal', 'Angelique' and 'Gold Medal' were studied to achieve better management, quality production and ascertaining salinity tolerance of promising cut roses being grown commercially in Pakistan. Plants were grown in pure sand in order to eliminate substrate salinity effect on plants. Number of leaves $branch^{-1}$, leaf area, leaf total chlorophyll contents, bud diameter, flower diameter and flower quality were greater when plants were grown with canal water (control) having only 0.4 dS m^{-1} salinity, which also reduced interval between flushes by early flowering, while plant height, number of flowers $plant^{-1}$ $flush^{-1}$, fresh and dry weight of a flower, stem length and diameter were greater with 2.5 dS m^{-1} substrate salinity followed by canal water (control). Among cultivars, 'Angelique' proved comparatively more salt tolerant as compared with 'Kardinal' and 'Gold Medal' by producing vigorous growth and greater number of flowers. In summary, cut rose cultivars studied cannot tolerate higher substrate salinity and preferably be grown with < 2.5 dS m^{-1} NaCl substrate salinity.

Keywords: Cut flowers, Kardinal, NaCl, Production, Rose, Salinity.

INTRODUCTION

Cut rose is one of the leading cut flower in global floriculture trade on account of its commercial importance and aesthetic appeal. It belongs to the family Rosaceae and genus Rosa containing 200 species and more than 18,000 cultivars (Gudin, 2000; Mercurio, 2007; Ahmad *et al.*, 2012). It has always had a special place in our culture as there is hardly any event where roses are not displayed. Cut roses play an important role in interior decoration and add charm to different social occasions. Pakistan being an agricultural economy with diverse agro-climatic conditions has a great potential for the production of cut roses. According to a survey, roses are being grown as cut flowers on 1,300 acres of land in Punjab, Pakistan (Khan, 2005).

Substrate salinity, one of the major factors limiting horticultural productivity in both arid and semi-arid regions, is often characterized by high salt contents in root zone some of which adversely affect plant growth and cause considerable damage to final yield. It affects various physiological and biochemical processes of the plants and reduces water absorption through roots. Situation becomes worse when plants are supplied with water having higher salt levels. A mixture of sodium, calcium, magnesium, chloride, sulphates and carbonates may be present in saline soils and/or water, generally dominated by sodium and chloride (Rozema, 1995). Presence of Na^+ and Cl^- in the rhizosphere may disrupt the nutrients uptake directly by interfering with transporters, e.g., those for K^+ and NO_3^- in the root plasma membrane (Tester and Devenport, 2003) or may be metabolically toxic, if accumulated and not compartmentalized in vacuoles, causing leaf burning and scorching(Shannon and Grieve, 1999). Additionally, root growth may also be inhibited due to higher external salt concentrations by osmotic effects (Wild, 1988). Cut flowers, like many other horticultural crops, have no or little tolerance to salinity and exposure to salt stress may result in tissue injury or even plant death (Grattan and Grieve, 1999).

Proper management of water and nutrients is necessary for cut flower production as their suboptimal or excessive application may lead to reduced growth, less yield and poor quality (Oki and Lieth, 2004). Commercial production of roses for cut flowers is the most intensive horticultural cropping system, demanding high water and nutrient inputs (Ahmad *et al.*, 2010). Roses are categorized as a salt sensitive species, with yield and quality reductions reported when the electrical conductivity (EC) of the saturated soil paste is ≥ 3.0 dS m^{-1} (Bernstein *et al*., 1972; Cabrera, 2003; Bar-Yousaf *et al*., 2009). Such EC levels are easily reached in greenhouse roses, as the nutrient solutions used to irrigate them typically range from 1-2 dS m^{-1}. This becomes exacerbated when recycling leached or run-off solutions, and using poor quality waters (Oki and Lieth, 2004; Raviv *et al.,* 1998). Salt stress causes both osmotic stress due to decreased soil water potential and ionic stress due to ion accumulation. For each condition and plant species, water and soil management must be properly defined with the aim of reducing hazardous effects of salts and optimizing plant nutrition (Chartzoulakis and Loupassaki, 1997). Urban *et al*. (1995) studied that flower yield and vase life were affected by EC in *Rosa hybrida* cv. Sonia grown in soilless conditions with nutrient solution having ECe of 1.8 or 3.8 mS cm^{-1}. Transpiration rate varied because of similar change of water uptake, whereas, water balance remained unaltered. Shoot elongation in *Rosa hybrida* cv. 'Lambada' is negatively correlated with sodium concentration; although no external symptoms of toxicity were observed (Lorenzo *et al.,* 2000), which indicates possible blockage of vascular system by sodium. When plants of *Rosa hybrida* L. 'Kardinal' are exposed to NaCl salinized nutrient solutions to study the changes in stem elongation rates in either 2 or 12 h, the increased solution electrical conductivity (EC) reduced the shoot growth rate (Oki and Lieth, 2004).

Stem length is a vital quality attribute of cut roses to growers since it influences the economic value of the crop. According to one hypothesis, shoot elongation and leaf expansion are the most sensitive growth processes to water and salt stress (Kreij *et al*., (1990); Wahome *et al*., (2000). Due to high transpiration rates of growing stems and leaves, they are particularly sensitive to water and salt stress. Roses grown as cut flowers in greenhouses are harvested year round which promote the continuous production of new, young shoots and foliage and make these plants more sensitive to salt stress (Raviv and Blom, 2001). Presence of high concentrations of soluble salts in irrigation water blocks vascular system and ultimately restrict water uptake. It results in water stress which causes loss of cell turgidity and reduction in leaf expansion rates. This, in return, leads to a reduction in leaf area available for photosynthesis causing loss of yield and quality (Kool and Lenssen, 1997). Therefore, in order to maximize productivity and stem quality, adequate quantity of good quality water should be provided to the plants.

According to a survey, > 6% (932 million ha) of total land area on this earth is covered by salt affected soils (Rengasamy, 2006; Szabolcs, 1991), while in Pakistan, about 24% (4.8 million ha) of irrigated land is salt affected (Mujtaba *et al.*, 2003). Salinity may also diminish aesthetic value and quality of cut stems (Morales *et al*., 1998). These problems necessitated to screen various cut rose cultivars for selection of salt tolerant ones, which can be successfully grown under moderately saline conditions. Moreover, with diminishing quality water resources and increase in competition for high quality water, it was hypothesized that saline water may affect cut rose production adversely. Based on the socio-economic value and ever high market demand of the selected cut rose cultivars, this study was conducted with the primary objective of optimizing pre-harvest salinity tolerance for achieving better growth, flower yield and quality and to evaluate the salinity tolerance, as shown by plant growth and quality, of three popular, highly demanded cut rose cultivars.

MATERIALS AND METHODS

A study was conducted at the Floriculture Greenhouse, Institute of Horticultural Sciences, University of Agriculture, Faisalabad (latitude 31°30N, longitude 73°10E and altitude 213m) where the average maximum and minimum temperatures were maintained at 30 ± 2°C and 16 ± 2°C, respectively, during study period from February to May. Average maximum and minimum relative humidity were 73 and 39%, respectively. Three *R. hybrida* L., cultivars viz. 'Kardinal', 'Angelique' and 'Gold Medal' were grown at 30 cm between plants in 60 cm spaced rows in 15.0 m long, 1.0 m wide and 0.6 m deep sand filled trenches. Being inert matter, pure sand was used as growing substrate in order to eliminate substrate salinity effects. All plants were uniformly pruned to equal height (15 cm above bud union) during last week of December. After six weeks of pruning, when plants started sprouting, salinity levels were developed by adding NaCl to canal water, which was applied to the applied in uniform quantity according to the treatments. There were five salinity levels viz. control (0.4 dS m^{-1}), 2.5 dS m^{-1}, 5.0 dS m^{-1}, 7.5 dS m^{-1} and 10.0 dS m^{-1}. Experiment was laid out according to completely randomized design with factorial arrangements having ten plants per treatment each with three replications. All other cultural practices like fertilization, weeding, and plant protection were similar for all treatments during study period. Data regarding plant height (cm), number of leaves $branch^{-1}$, leaf area (cm^2), leaf total chlorophyll contents (mg g^{-1}), days to flower emergence, number of flowers $plant^{-1}$ $flush^{-1}$, bud diameter (cm), flower diameter (cm), fresh weight of a flower (g), dry weight of a flower (g), flower quality, stem length (cm) and stem diameter (cm) were collected. Flower quality was rated on a scale ranging from 1-9, where 9 was considered best quality without any defect, and 1 was poor quality stems with small sized, malformed or diseased flowers (Cooper and Spokas, 1991; Dest and Guillard, 1989). Data collected were analyzed statistically by using the method described by Steel *et al*., (1997).

RESULTS

Plants grown in a substrate with 2.5 dS m-1 salinity level produced taller plants (53.8 cm) followed by control, in which plants were supplied with canal water having 0.4 dS m^{-1} EC, 5.0 dS m^{-1} and 7.5 dS m^{-1} which produced 52.9, 45.5 and 40.1 cm plant height, respectively. Whereas, 10.0 dS m^{-1} produced short stature plants with 33.7 cm height (Table 1). Among cultivars, 'Angelique' produced taller plants with 46.6 cm height followed by 'Kardinal' (45.7 cm), while 'Gold

Medal' produced short statured plants (43.3 cm; Table 2). Plants supplied with canal water (having 0.4 dS m^{-1} EC) and 2.5 dS m^{-1} produced greater leaves $branch^{-1}$ (14.4 and 12.7, respectively) followed by 5.0 and 7.5 dS m^{-1} which produced 10.3 and 8.5 leaves $branch^{-1}$, respectively (Table 1). Among cultivars, 'Angelique' had more leaves $branch^{-1}$ (11.4) followed by 'Kardinal' (11.1), while 'Gold Medal' had less number of leaves $branch^{-1}$ (9.3; Table 2).

Plants grown without NaCl application (control) had higher leaf area (32.3 cm^2) followed by 2.5, 5.0 and 7.5 dS m^{-1}) which had 30.6, 26.0, and 21.0 cm^2 leaf area, respectively (Table 1). Whereas, those having 10.0 dS m^{-1} EC had smaller leaf area (16.3 cm^2). Among cultivars, 'Angelique' had greater leaf area (26.3 cm^2) followed by 'Kardinal' (25.0 cm^2), while 'Gold Medal' had smaller leaf area (24.4 cm^2). Plants without salinity application had higher total leaf chlorophyll contents (50.6 mg g^{-1}) followed by 2.5, 5.0 and 7.5 dS m^{-1} (48.5, 44.0 and 40.6 mg g^{-1}, respectively; Table 1). While, plants grown with 10.0 dS m^{-1} salinity has less total chlorophyll contents (36.1 mg g^{-1}). 'Kardinal' had greater total leaf chlorophyll contents (47.0 mg g^{-1}) than 'Gold Medal' (44.2 mg g^{-1}) and 'Angelique' (40.7 mg g^{-1}; Table 2).

Analysis of variance for days to flower emergence revealed significant differences among salinity levels and cultivars. Among salinity levels, no NaCl application produced early flowering after 65.9 days followed by 2.5 dS m^{-1}, 5.0 dS m^{-1} and 7.5 dS m^{-1} (67.8, 69.9 and 72.0 days, respectively; Table 3). However, plants grown in 10.0 dS m^{-1} salinity flowered later (74.1 days). Among cultivars, 'Kardinal' 'flowered earlier after 66.4 days, 'Gold Medal' after 74.3 days and 'Angelique' after 69.1 days (Table 4). Plants grown with 2.5 dS m^{-1} and without NaCl application (control) produced more flowers $plant^{-1}$ $flush^{-1}$ (5.5 and 5.4, respectively), and were statistically at par, followed by 5.0 and 7.5 dS m^{-1} (4.8 and 4.0 flowers $plant^{-1}$ $flush^{-1}$, respectively; Table 3). Roses grown in a substrate with 10.0 dS m^{-1} EC produced minimum flowers $plant^{-1}$ (3.4) in a flush. Among cultivars, 'Angelique' produced higher number of flowers $plant^{-1}$ $flush^{-1}$ (6.0) than 'Kardinal' (4.1) and 'Gold Medal' (3.8; Fig. 1).

Plants without NaCl application (control) and 2.5 dS m^{-1} had greater bud diameter (3.1 and 2.9 cm, respectively), and were statistically at par, followed by 5.0 and 7.5 dS m^{-1} (2.6 and 2.4 cm, respectively; Table 3). While, plants grown with 10.0 dS m^{-1} EC had smaller bud diameter (2.1 cm). 'Angelique' had higher bud diameter (2.7 cm) than 'Kardinal' and 'Gold Medal' '(2.6 cm each). Plants grown without NaCl application (control) and with 2.5 dS m^{-1} EC had higher flower diameter (6.2 and 6.1 cm, respectively), and were statistically similar, followed by 5.0 dS m^{-1} and 7.5 dS m^{-1} (5.6 and 5.1 cm, respectively; Table 3). However, those grown with 10.0 dS m^{-1} EC had smaller flower diameter (4.7 cm). Among cultivars, 'Kardinal' had greater flower diameter (5.6 cm) than 'Angelique' (5.6 cm) and 'Gold Medal' (5.5 cm; Table 4).

Plants with 2.5 dS m^{-1} and no salinity application (control) had higher fresh weight of a flower (3.1 and 3.0 g, respectively), and were statistically at par, than 5.0 dS m^{-1} and 7.5 dS m^{-1} (2.7 and 2.4 g, respectively; Table 3). While those grown with 10.0 dS m^{-1} salinity level had less fresh weight of a flower (2.2 g). Among cultivars, 'Angelique' had higher fresh weight of a flower (2.8 g) than 'Kardinal' (2.6 g) and 'Gold Medal' (2.6 g; Table 4). For dry weight of a flower, plants supplied with 2.5 dS m^{-1} and no NaCl application (control) had higher dry weight of a flower (1.1 g each), and were statistically similar, followed by 5.0 dS m^{-1} (0.9 g; Table 3). While plants grown with 10.0 dS m^{-1} and 7.5 dS m^{-1} had less dry weight of a flower (0.5 and 0.6 g, respectively) and were statistically similar. All cultivars had similar dry weight of a flower (Table 4).

Plants grown with canal water without NaCl application (control) and 2.5 dS m^{-1} produced best quality flowers with 6.4 and 6.2 rating on a scale of 1-9, respectively, and were statistically similar, followed by 5.0 and 7.5 dS m^{-1} EC (5.2 and 4.3, respectively; Fig. 2). Whereas, roses grown with 10.0 dS m^{-1} EC level had poor quality flowers with 3.6 rating on a 1-9 scale. Among cultivars, 'Kardinal' had best quality (5.6) flowers followed by 'Angelique' (5.0) and 'Gold Medal' (4.7; Fig. 2). Plants supplied with 2.5 dS m^{-1} and no NaCl application (control) had longer stem length (34.3 and 33.3 cm, respectively), and were statistically similar, than 5.0, 7.5 and 10.0 dS m^{-1} (25.2, 20.6 and 18.0 cm, respectively) as shown in Fig. 3. 'Angelique' produced longer stem length (28.9 cm) than 'Kardinal' (26.9 cm) and 'Gold Medal' (23.1 cm). Plants grown in substrate containing 2.5 dS m^{-1} EC or without NaCl application (control) had greater stem diameter (0.37 and 0.34 cm, respectively) and were statistically at par, followed by 5.0 and 7.5 dS m^{-1} (0.27 and 0.22 cm, respectively; Fig. 4). Plants grown with 10.0 dS m-1 EC level had smaller stem diameter (0.19 cm). Among cultivars, 'Kardinal' had greater stem diameter (0.32 cm) than 'Angelique' (0.27 cm) and 'Gold Medal' (0.26 cm).

DISCUSSION

Among global environmental issues, salinity stress is the most important issue which reduces crop yield by interacting among different physiological, morphological, and biochemical processes (Munns and Tester, 2008). Plants grown under saline conditions have retarded growth and short stature (Shannon and Grieve, 1999), caused by disturbance to water and ion balance, membrane permeability, stomatal conductivity, and photosynthesis (Carvajal *et al*., 1999; Navarro *et al.*, 2003; Cabañero *et al*., 2004). This reduction in growth is used to quantify the salinity resistance in different crops (Sánchez-Blanco *et al.*, 1991).

In our study, cut stems grown with 0.4 dS m^{-1} EC (control) produced greater number of leaves $branch^{-1}$, leaf area, total leaf chlorophyll contents, produced flowers earlier, had higher bud diameter, flower diameter and flower quality as compared with those plants which were grown under saline conditions. A curvilinear reduction was observed in plant growth with increase in substrate salinity. These results were in line with the findings of Kreij *et al*., (1990); Wahome *et al*., (2000), and Raviv and Blom (2001) who reported roses as highly salt sensitive species and affected adversely with increase in substrate salinity. Plants grown under saline conditions had reduced leaf area, which might be due to water stress that reduced leaf expansion rate. Reduction in available leaf area for photosynthesis is also linked with inability of the plant to adjust osmotically (Auge *et al.,* 1990), which in turn linked with loss of yield (Kool and Lessen, 1997). Plants grown with 2.5 dS m^{-1} substrate EC produced taller plants with higher flower yield $plant^{-1}$ $flush^{-1}$, fresh and dry weight of a flower and stem length, which decreased with further increasing salinity. Stem length, an important quality factor which affects cut flower final market price, was also greatly affected by increase in salinity (Oki and Lieth, 2004). Increase in NaCl concentration significantly reduced the stem length of cut 'Kardinal' roses (Wahome *et al.*, 2000), and 'Cheerful White' and 'Frolic Carmine' stock (Grieve *et al*., 2006). Both treatments, no NaCl application (control) and 2.5 dS m^{-1}, were equally good for producing thicker stems with greater stem diameter, while other treatments with higher salinity concentrations had smaller stem diameter. Among different cultivars, 'Angelique' produced taller plants with more foliage $branch^{-1}$, greater leaf area, number of flowers $plant^{-1}$ $flush^{-1}$, bud diameter, fresh and dry weight of a flower, and stem length, while 'Kardinal' had higher total chlorophyll contents, earlier flower emergence, flower diameter, flower quality and stem diameter. These results revealed cultivar variability in salinity tolerance which has been reported in many studies. For example, an increase in EC from 1.25 to 2.75 dSm^{-1} was detrimental to 'Forever Yours' (Hughes and Hanan, 1978) and only 5mM NaCl (≈0.5 dSm^{-1}) reduced stem lengths of 'Kardinal' (Wahome *et al*., 2000). In contrast, 'Sonia' yield was not affected by an EC of 3.8 dSm^{-1} (Urban *et al*., 1994) and Cabrera (2001) found no effect on stem lengths of 'Bridal Pink' with up to 30mM NaCl (≈2.9 dSm^{-1}) suggesting a cultivar dependent tolerance to substrate salinity. Moreover, in some species/ cultivars, the salinity tolerance is based on limited ion uptake by roots, or their restricted translocation to aerial plant parts (Picchioni and Graham, 2001). Some studies have also reported that some rose cultivars are fairly salt tolerant and have no negative effect of NaCl salinity on yield, dry matter and quality (Cabrera, 2001; Cabrera and Perdomo, 2003).

This study revealed that tested cut rose cultivars were quite salt sensitive and with gradual increase in substrate salinity, yield and quality of the cut stems decreased which was evident from reduction in flower yield, stem length, stem diameter, and weight of the flowers. Higher salt concentrations may have affected metabolic activities by blocking the vascular tissues and increasing salt concentration in cells that might be responsible for cell death and ultimate reduction in growth, yield and quality (Hughes and Hanan, 1978). Moreover, among cultivars, "Angelique' could be the better option to be grown in areas with comparatively higher salt levels as it proved comparatively salt tolerant than others and 'Gold Medal' and 'Kardinal' should not be grown in areas with higher substrate salinity or poor quality water. The salt tolerance of 'Angelique' might be due to its ability to retain Na^+ and Cl^- to roots and limit their uptake and/ or transport to the aerial plant parts (Murillo-Amador *et al.*, 2006). Another reason might be its ability to maintain a higher K^+/Na^+ ratio in its tissues as compared with other cultivars (Munns and James, 2003).

In conclusion, rose cultivars used in this study were quite salt sensitive and their growth, yield and quality was adversely affected with increasing substrate salinity. Therefore, the tested cultivars should be grown in such soil/ medium which have less than 2.5 dS m^{-1} EC. Moreover, 'Angelique' was quite tolerant to fairly moderate salt concentrations than 'Kardinal' and 'Gold Medal' which advocated its suitability to be grown on moderately saline soils. For quality cut rose production, either artificial substrates with good quality water should be used in areas where higher substrate salinity exists, or poor quality water is available for irrigation. Moreover, saline soils should preferably be avoided for cut rose production in order to get vigorous growth and higher flower production of superior quality.

Literature Cited

Ahmad, I., Khan, M.A., Qasim, M., Ahmad, R. and Randhawa, M.A. 2010. Growth, yield and quality of *Rosa hybrida* L. as influenced by various micronutrients. Pak. J. Agri. Sci. 47:5-12.

Ahmad, I., Khan, M.A,. Qasim, M., Zafar, M.S. and Ahmad, R. 2012. Substrates effects on growth, yield, and quality of *Rosa hybrida* L. Pak. J. Bot. 44:177-185.

Auge, R.M., Stodola, A.J.W. and Pennell, B.D. 19990. Osmotic and turgor adjustment in Rosa foliage drought-stressed under varying irradiance. J. Amer. Soc. Hort. Sci. 115:661–667.

Bar-Yousef, B., Matton, N.S. and Lieth, H.J. 2009. Effects of NH4:NO3: urea ratios on cut roses yield, leaf nutrients content and proton efflux by roots in closed hydroponic system. Sci Hort. 122:610-619.

Bernstein, L., Francois, L.E. and Clark, R.A. 1972. Salt tolerance of ornamental shrubs and ground covers. J. Amer. Soc. Hort. Sci. 97:550-556.

Cabañero, F.J., Martıñez, V. and Carvajal, M. 2004. Does calcium determine water uptake under saline conditions in pepper plants, or is it water flux which determines calcium uptake? Plant Sci. 166:443–450.

Cabrera, R.I. 2001. Effect of NaCl salinity and nitrogen fertilizer formulation on yield and nutrient status of roses. Acta Hort. 547:255-260.

Cabrera, R.I. 2003. Demarcating salinity tolerance in greenhouse rose production. Acta Hort. 609:51–57.

Cabrera, R.I. and Perdomo, P. 2003. Reassessing the salinity tolerance of greenhouse roses under soilless production conditions. HortScience. 38:533-536.

Carvajal, M., Martıñez, V. and Cerda, A. 1999. Influence of magnesium and salinity on tomato plants grown in hydroponic culture. J. Plant Nutr. 22:177–190.

Chartzoulakis, K. and Loupassaki, M. 1997. Effects of NaCl salinity on germination, growth, gas exchange and yield of greenhouse eggplant. Agric. Water Manag. 32:215-225.

Cooper, R.J. and Spokas, L.A. 1991. Growth, quality and foliar iron concentration of Kentucky bluegrass treated with chelated iron source. J. Amer. Soc. Hort. Sci. 116:798-801.

Dest, W.M. and Guillard, K. 1987. Nitrogen and phosphorus nutritional influence on bentgrass. J. Amer. Soc. Hort. Sci. 112:769-773.
Grieve, C.M., Poss, J.A. and Amrhein, C. 2006. Response of *Matthiola incana* to irrigation with saline wastewaters. HortScience. 41:119-123.
Gudin, S. 2000. Rose Genetics and Breeding. p. 159-189. In: Janick, J. (ed.). Reviews. Vol. 17. John Wiley & Sons, Inc. NY.
Hughes, H. and Hanan, J. 1978. Effect of salinity in water supplies on greenhouse rose production. J. Amer. Soc. Hort. Sci. 103:694-699.
Khan, M.A. 2005. Development of commercial floriculture in Asia and Pacific: Issues, challenges and opportunities. Proc. National Seminar on Streamlining Production and Export of Cut Flowers and House Plants. Saeed, A. (ed.) Hort. Foundation, Pakistan. 2 -4 March. p. 36.
Kool, M.T.N. and Lenssen, E.F.A. 1997. Basal shoot formation in young rose plants: effects of bending practices and plant density. J. Hort. Sci. 72:635-644.
Kreij, C. de., Berg, T.J. and van Den, M. 1990. Nutrient uptake, production and quality of *Rosa hybrida* in rockwool as affected by electrical conductivity of the nutrient solution. Proc. 11th Intl. Pl. Nutri. Colloquim, Wageningen, Netherlands, 30 July – 4 August, 1989. p. 519-523.
Lorenzo, H., Cid, M.C., Siverio, J.M. and Ruano, M.C. 2000. Effects of sodium on mineral nutrition in rose plants. Annal. Appl. Biol. 137:65-72.
Mercurio, G. 2007. Cut Rose Cultivation Around the World. Schreurs, The Netherlands. p. 81-88.
Morales, M.A., Sanchez-Blanco, M.J., Olmos, E., Torecillas, A. and Alarcon, J.J. 1998. Changes in the growth, leaf water relations and cell ultrastructure in *Argyranthemum coronopifolium* plants under saline conditions. J. Pl. Physiol. 153:174-180.
Mujtaba, S.M., Mughal, S. and Naqvi, M.H. 2003. Reclamation of saline soils through biological approaches. IUCN Pak. Water gateway.
Munns, R. and James, R.A. 2003. Screening methods for salinity tolerance: a case study with tetraploid wheat. Plant Soil. 253:201–218.
Munns, R. and Tester, M. 2008. Mechanisms of salinity tolerance. Ann. Rev. Plant Physiol. 59:651–681.
Murillo-Amador, B., Troyo-Diéguez, E., Garcıá-Hernańdez, J.L., López-Aguilar, R., Ávila-Serrano, N.Y., Zamora-Salgado, S., Rueda-Puente, E.O. and Kaya, C. 2006. Effect of NaCl salinity in the genotypic variation of cowpea (*Vigna unguiculata*) during early vegetative growth. Sci. Hort. 108:423–441.
Navarro, J.M., Garrido, C., Martínez, V. and Carvajal, M. 2003. Water relations and xylem transport of nutrients in pepper plants grown under two different salts stress regimes. Plant Growth Regul. 41:237–245.
Oki. L.R. and Lieth, J.H. 2004. Effect of changes in substrate salinity on elongation of *Rosa hybrida* L. 'Kardinal' stems. Sci. Hort. 101:103-119.
Picchioni, G.A. and Graham, C.J. 2001. Salinity, growth, and ion uptake selectivity of container-grown *Crataegus opaca*. Sci. Hort. 90:151–166.
Raviv, M. and Blom, T.J. 2001. The effect of water availability and quality on photosynthesis and productivity of soilless grown cut roses. Sci. Hort. 88:257-276.
Raviv, M., Krasnovsky, A., Medina, S. and Reuveni, R. 1998. Assessment of various control strategies for recirculation of greenhouse effluents under semi-arid conditions. J. Hort. Sci. Biotech. 73:485-491.
Rengasamy, P. 2006. World salinization with emphasis on Australia. J. Expt. Bot. 57:1017-1023.
Rozema, J. 1995. Biology of Halophytes. p. 17-30. In: Choubr-Allah, R., Malcolm, C.V. and Handy, A. (eds.). Halophytes and Biosaline Agriculture. Marcel Dekker, Inc. NY.
Shannon, M.C. and Grieve. C.M. 1999. Tolerance of vegetable crops to salinity. Sci. Hort. 78:5–38.
Steel, R.G.D., Torrie, J.H. and Dicky, D.A. 1997. Principles and Procedures of Statistics: A Biometric Approach. (3rd ed.) Mc. Graw Hill, Inc., NY.

Szabolcs, I. 1991. Desertification and salinization. p. 3-18. In: Choukr-Allah R. (ed.). Plant Salinity Research. Proc. Intl. Conference on Agricultural Managements of salt affected areas held in Agadir, Morocco, April 26-May 3.

Tester, M. and Davenport, R. 2003. Na+ tolerance and Na+ transport in higher plants. Ann. Bot. 91:503–527.

Urban, L., Brun, R. and Pyrrha, P. 1994. Water relations of leaves of ‘Sonia’ rose plants grown in soilless greenhouse conditions. HortScience. 29:627–630.

Urban, L., Jaffrin, A. and Burn, R. 1995. Control of salinity in the rhizosphere of plants grown in soil-less media. Acta Hort. 408:73-80.

Wahome, P.K., Jesch, H.H. and Grittner, I. 2000. Effect of NaCl on the vegetative growth and flower quality of roses. J. Appl. Bot. 74:38-41.

Wild, A. 1988. Russell’s Soil Conditions and Plant Growth. 11th ed. Longman, Harlow.

Tables

Table 1. Plant height, number of leaves branch^{-1}, leaf area and total leaf chlorophyll contents of *Rosa hybrida* L. as influenced by NaCl substrate salinity. Means are the averages of 30 samples of three replicates.

Treatments	Plant height (cm)	Number of leaves branch^{-1}	Leaf area (cm^2)	Total chlorophyll contents (mg g^{-1})
Control (0.4 dS m^{-1})	52.9 a[1]	14.4 a	32.3 a	50.6 a
2.5 dS m^{-1}	53.8 a	12.7 a	30.6 ab	48.5 ab
5.0 dS m^{-1}	45.5 bc	10.3 b	26.0 bc	44.0 bc
7.5 dS m^{-1}	40.1 cd	8.5 bc	21.0 cd	40.6 cd
10.0 dS m^{-1}	33.7 d	7.1 c	16.3 d	36.1 d

[1] Means sharing similar letters in a column are statistically non-significant at $p \leq 0.05$.

Table 2. Plant height, number of leaves branch^{-1}, leaf area and total leaf chlorophyll contents of *Rosa hybrida* L. cvs. 'Kardinal', 'Angelique' and 'Gold Medal' as influenced by NaCl substrate salinity. Means are the averages of 30 samples of three replicates

Treatments	Plant height (cm)	Number of leaves branch^{-1}	Leaf area (cm^2)	Total chlorophyll contents (mg g^{-1})
Kardinal	45.7 a[1]	11.1 a	25.0 a	47.0 a
Angelique	46.6 a	11.4 a	26.3 a	40.7 b
Gold Medal	43.3 a	9.3 b	24.4 a	44.2 ab

[1] Means sharing similar letters in a column are statistically non-significant at $p \leq 0.05$.

Table 3. Days to flower emergence, bud diameter, flower diameter, and fresh and dry weight of a flower of *Rosa hybrida* L. as influenced by NaCl substrate salinity. Means are the averages of 30 samples of three replicates.

Treatments	Days to flower emergence	Bud diameter (cm)	Flower diameter (cm)	Fresh weight of a flower (g)	Dry weight of a flower (g)
Control	65.9 e[1]	3.1 a	6.2 a	3.0 a	1.1 a
2.5 dS m^{-1}	67.8 d	2.9 a	6.1 a	3.1 a	1.1 a
5.0 dS m^{-1}	69.9 c	2.6 b	5.6 b	2.7 b	0.9 b
7.5 dS m^{-1}	72.0 bd	2.4 c	5.1 c	2.4 c	0.6 c
10.0 dS m^{-1}	74.1 a	2.1 d	4.7 d	2.2 d	0.5 c

[1]Means sharing similar letters in a column are statistically non-significant at $p \leq 0.05$.

Table 4. Days to flower emergence, bud diameter, flower diameter, and fresh and dry weight of a flower of *Rosa hybrida* L. cvs. 'Kardinal', 'Angelique' and 'Gold Medal' as influenced by NaCl substrate salinity. Means are the averages of 30 samples of three replicates

Cultivars	Days to flower emergence	Bud diameter (cm)	Flower diameter (cm)	Fresh weight of a flower (g)	Dry weight of a flower (g)
Kardinal	66.4 c[1]	2.6 a	5.6 a	2.6 a	0.8 a
Angelique	69.1 b	2.7 a	5.6 a	2.8 a	0.9 a
Gold Medal	74.3 a	2.6 a	5.5 a	2.6 a	0.8 a

[1] Means sharing similar letters in a column are statistically non-significant at $p \leq 0.05$.

Figures

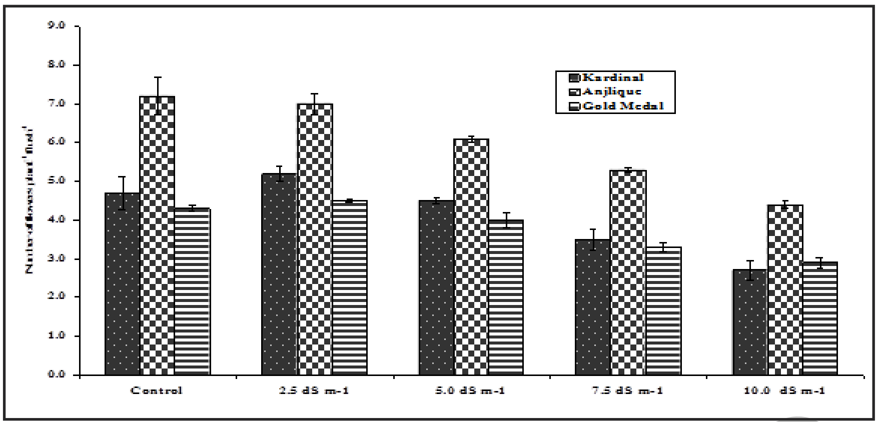

Fig. 1. Number of flowers plant^{-1} flush^{-1} of *Rosa hybrida* L. cvs. 'Kardinal', Angelique' and 'Gold Medal' as influenced by NaCl substrate salinity. Means are the averages of 30 samples of three replicates.

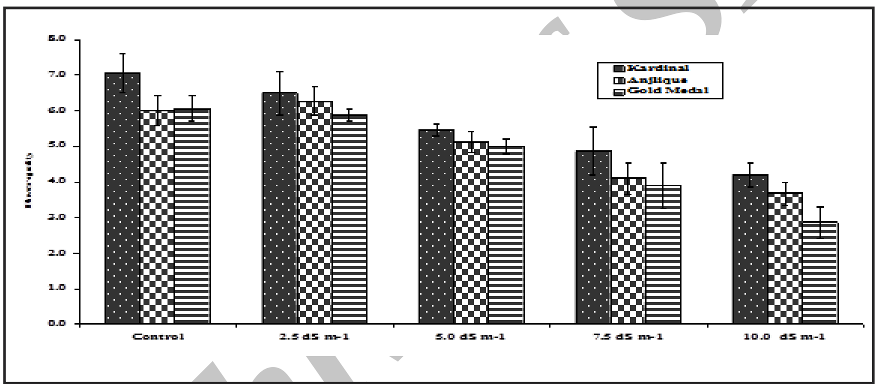

Fig. 2. Flower quality of *Rosa hybrida* L. cvs. 'Kardinal', 'Angelique' and 'Gold Medal' as influenced by NaCl substrate salinity. Means are the averages of 30 samples of three replicates

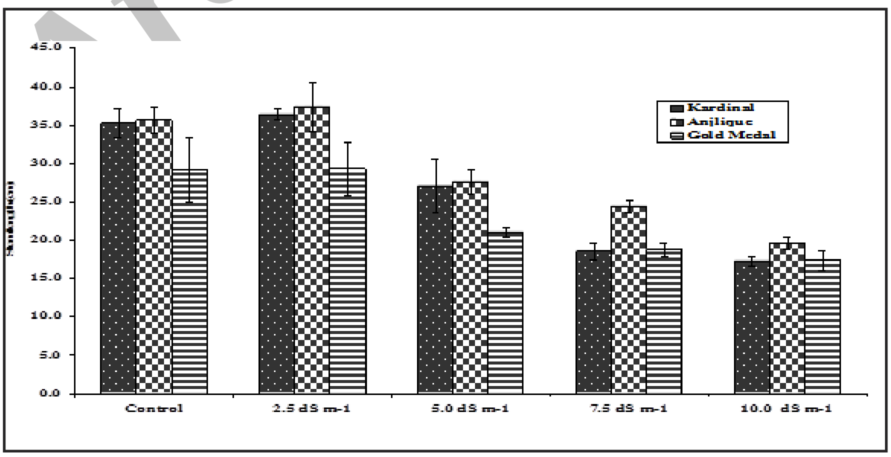

Fig. 3. Stem length (cm) of *Rosa hybrida* L. cvs. 'Kardinal', 'Angelique' and 'Gold Medal' as influenced by NaCl substrate salinity. Means are the averages of 30 samples of three replicates.

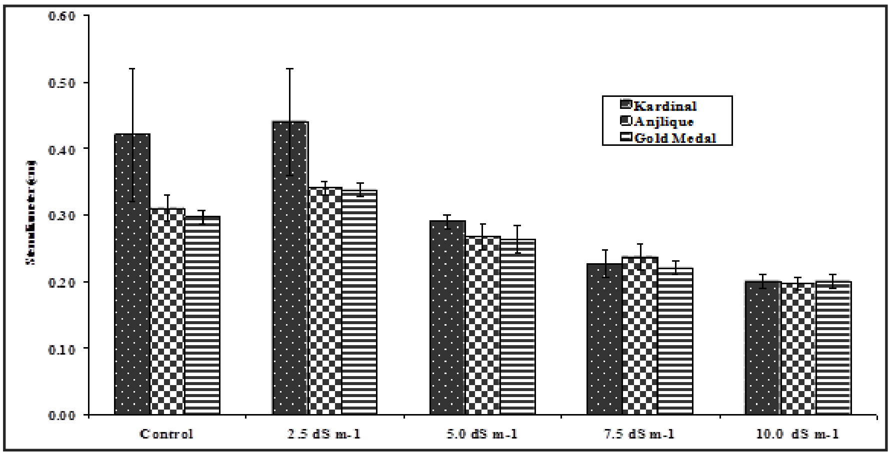

Fig. 4. Stem diameter (cm) of *Rosa hybrida* L. cvs. 'Kardinal', 'Angelique' and 'Gold Medal' as influenced by NaCl substrate salinity. Means are the averages of 30 samples of three replicates.