SUBSTRATE SALINITY AFFECTS GROWTH, YIELD AND QUALITY OF *ROSA HYBRIDA* L.

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ABSTRACT: The effects of NaCl salinity (control (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', 'Anjlique' and 'Gold Medal' was studied to achieve better management, quality production and ascertaining salinity tolerance of cut roses. 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, flower stem length and diameter were higher with 2.5 dSm^{-1} substrate salinity followed by canal water (control). Among cultivars, 'Anjlique' proved comparatively salt tolerant as compared with 'Kardinal' and 'Gold Medal' by having vigorous growth and higher flowering attributes. In summary, cut roses can not tolerate higher substrate salinity and should be grown with less than 2.5 dS m^{-1} sodium chloride concentration in the substrate.

Key words: Cut flowers, flowering, growth, NaCl, rose, salinity.

INTRODUCTION

Rose, a symbol of love, affection, elegance, inspiration, sensuality, spirituality and source of aesthetic gratification for human beings, is one of the leading cut flower in global floriculture trade. It belongs to family Rosaceae and genus Rosa, which contains 200 species and more than 18,000 cultivars (Gudin, 2000). Rose has always been the most favorite flower in the subcontinent. It has always had a special place in our culture as there is hardly any event where roses are not displayed in varied fashion. Cut rose flowers 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 in a variety of ways which reduces water absorption by plant roots from soil solution required for proper plant growth and development. A mixture of sodium, calcium, magnesium, chloride, sulphates and carbonates may be present in saline soils, generally dominated by sodium and chloride (Rozema, 1995). Commercial production of roses for cut flowers is the most intensive horticultural cropping system, demanding high water and nutrient inputs (Cabrera, 1992). 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 $\geq$ 3 dS m^{-1} (Bernstein *et al.,* 1972; Hughes and Hanan, 1978). 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} (Cabrera, 1992; White, 1987). This is also exacerbated when recycling leached or run-off solutions, when practicing minimum leaching and using poor quality waters (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's ECe of 1.8 or 3.8 mS cm^{-1}. Transpiration rates 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). When plants of *Rosa hybrida* L. 'Kardinal' are exposed to salinized nutrient solutions to study the changes in stem elongation rates for 2 or 12 h with NaCl to increase the solution electrical conductivity (EC) by 1, 2, 4, or 8 dS m^{-1} (+1, +2, +4, and +8, respectively), treatment with NS resulted in a growth rate 0.10 mm h^{-1} greater than the pretreatment rate.

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 (Hsiao, 1990). Due to high transpiration rates of growing stems and leaves, they are particularly sensitive to water and salt stress (Jones, 1992). 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 will cause loss of cell turgor and reduction in leaf expansion rates (Jones, 1992). This, in return, leads to a reduction in leaf area available for photosynthesis which will cause a loss of yield and quality (Kool and Lenssen, 1997).

According to a survey, around 10% of total dry land on this earth is covered by salt affected soils (Szaboles, 1991) while in Pakistan, about 6.8 million ha of land is salt affected (Khan, 1998). Salinity may also affect ornamental value and quality of flowers (Morales *et al.,* 1998). These problems necessitated to screen various rose cultivars for selection of salt tolerant ones, which can be successfully grown under moderately saline conditions. Keeping in view the socio-economic value and ever high market demand of this potential cut flower species, this study was conducted with the specific objective of optimizing pre-harvest salinity tolerance for achieving better growth, flower yield and quality and to compare the best three cut rose cultivars, which have high demand in local market, for their salinity tolerance.

MATERIALS AND METHODS

The study was conducted at 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 30 ± 2°C and 16 ± 2°C, respectively, during study period. Average maximum and minimum relative humidity were 73 and 39%, respectively. Three *R. hybrida* L., cultivars viz. ‘Kardinal’, ‘Anjlique’ and ‘Gold Medal’ were grown at 30 cm between plants in 60 cm spaced rows in sand filled trenches of 15.0, 1.0 and 0.6 m length, width and depth, respectively. 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 using NaCl and applied according to different 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 with ten plants per treatment each replicated thrice. All other cultural practices like fertilization, weeding, plant protection etc. were same 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 using standard procedures. 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, ‘Anjlique’ 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, ‘Anjlique’ 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, ‘Anjlique’ 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 ‘Anjlique’ (40.7 mg g^{-1}; Table 2).

Analysis of variance for days to flower emergence revealed significant ($P \leq 0.01$) 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 'Anjlique' 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, 'Anjlique' 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, those grown in 10.0 dS m^{-1} EC had smaller bud diameter (2.1 cm). 'Anjlique' 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 'Anjlique' (5.6 cm) and 'Gold Medal' (5.5 cm; Table 4).

Plants subjected to 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, 'Anjlique' 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. Among cultivars, 'Anjlique' had higher dry weight of a flower (0.9 g) than 'Kardinal' and 'Gold Medal' (0.8 g each) and were statistically at par (Table 4).

Plants grown with no 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 'Anjlique' (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

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 levels viz. no NaCl addition (canal water; 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}. 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 ab	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

Means sharing similar letters in a column are statistically non-significant at $P > 0.05$.

Table 2. Plant height, number of leaves $branch^{-1}$, leaf area and total leaf chlorophyll contents of *Rosa hybrida* L. cvs. 'Kardinal', 'Anjlique' and 'Gold Medal' as influenced by NaCl substrate salinity levels viz. no NaCl addition (canal water; 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}. Means are the averages of 30 samples of three replicates.

Cultivars	Plant height (cm)	Number of leaves $branch^{-1}$	Leaf Area (cm^2)	Total chlorophyll contents (mg g^{-1})
Kardinal	45.7 a	11.1 a	25.0 a	47.0 a
Anjlique	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

Means sharing similar letters in a column are statistically non-significant at $P > 0.05$.

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 levels viz. no NaCl addition (canal water; 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}. 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	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

Means sharing similar letters in a column are statistically non-significant at $P > 0.05$.

Table 4. Days to flower emergence, bud diameter, flower diameter, and fresh and dry weight of a flower of *Rosa hybrida* L. cvs. 'Kardinal', Anjlique' and 'Gold Medal' as influenced by NaCl substrate salinity levels viz. no NaCl addition (canal water; 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}. 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	2.6 a	5.6 a	2.6 a	0.8 a
Anjlique	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

Means sharing similar letters in a column are statistically non-significant at $P > 0.05$.

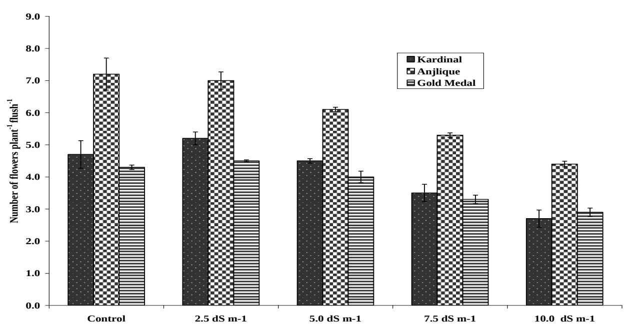

Fig. 1. Number of flowers $plant^{-1}$ $flush^{-1}$ of *Rosa hybrida* L. cvs. 'Kardinal', Anjlique' and 'Gold Medal' as influenced by NaCl substrate salinity levels viz. no NaCl addition (canal water; 0.4 dS m^{-1}), 2.5 dS m^{-1}, 5.0 dS m^{-1}, 7.5 dS m^{-1}, and 10.0 dS m^{-1}. Means are the averages of 30 samples of three replicates.

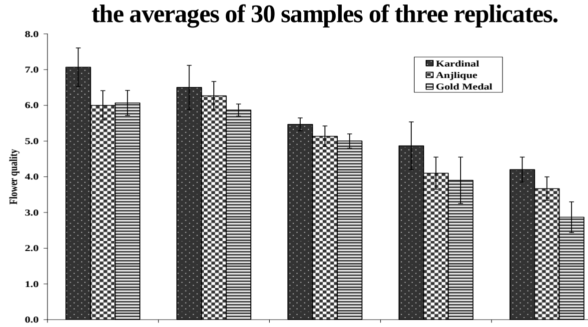

Fig. 2. Flower quality of *Rosa hybrida* L. cvs. 'Kardinal', Anjlique' and 'Gold Medal' as influenced by NaCl substrate salinity levels viz. no NaCl addition (canal water; 0.4 dS m^{-1}), 2.5 dS m^{-1}, 5.0 dS m^{-1}, 7.5 dS m^{-1}, and 10.0 dS m^{-1}. Means are the averages of 30 samples of three replicates.

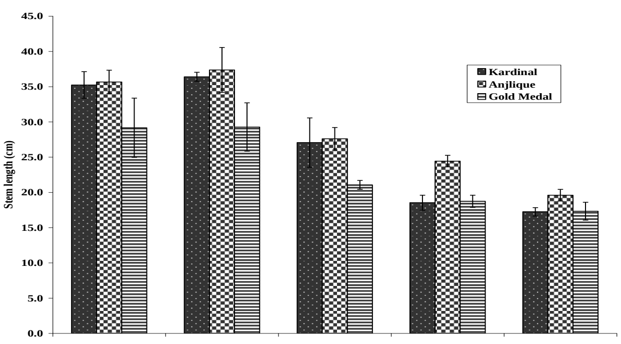

Fig. 3. Stem length (cm) of *Rosa hybrida* L. cvs. 'Kardinal', Anjlique' and 'Gold Medal' as influenced by NaCl substrate salinity levels viz. no NaCl addition (canal water; 0.4 dS m^{-1}), 2.5 dS m^{-1}, 5.0 dS m^{-1}, 7.5 dS m^{-1}, and 10.0 dS m^{-1}. Means are the averages of 30 samples of three replicates.

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. Among cultivars, 'Anjlique' produced longer stem length (28.9 cm) than 'Kardinal' (26.9 cm) and 'Gold Medal' (23.1 cm). Plants grown in a substrate containing 2.5 dS m^{-1} EC or no 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 'Anjlique' (0.27 cm) and 'Gold Medal' (0.26 cm).

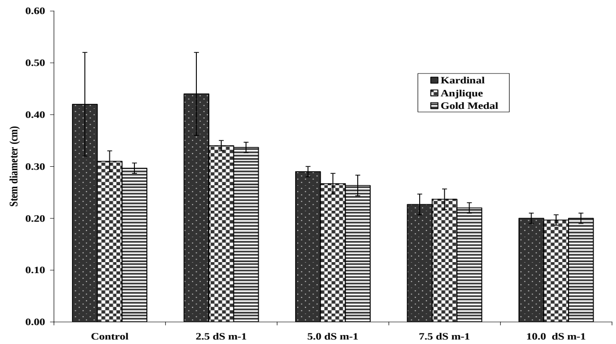

Fig. 4. Stem diameter (cm) of *Rosa hybrida* L. cvs. 'Kardinal', Anjlique' and 'Gold Medal' as influenced by NaCl substrate salinity levels viz. no NaCl addition (canal water; 0.4 dS m^{-1}), 2.5 dS m^{-1}, 5.0 dS m^{-1}, 7.5 dS m^{-1}, and 10.0 dS m^{-1}. Means are the averages of 30 samples of three replicates.

DISCUSSION

Commercial cut rose production is the most intensive horticultural cropping system, demanding good quality water and nutrient inputs (Cabrera, 1992). Salinity is a major factor that influences yield where climatic conditions are optimal (Lorenzo *et al.*, 2000). It has been observed that the number of flowers and average shoot length in rose cv. Sunlight decreased when grown under saline conditions (Ishida *et al.*, 1978). In this study, plants grown with 0.4 dS m^{-1} EC (control) produced greater number of leaves branch^{-1}, leaf area, total leaf chlorophyll contents, earlier flower emergence, higher bud diameter, flower diameter and flower quality; while 2.5 dS m^{-1} EC produced taller plants with higher number of flowers plant^{-1} flush^{-1}, fresh and dry weight of a flower and stem length while no NaCl application (control) and 2.5 dS m^{-1} both produced greater stem diameter. These results confirmed the findings of Raviv and Blom (2001) who reported roses as highly salt sensitive species which were affected adversely with increase in substrate salinity level in greenhouse while contrary to the observations of Agbaria *et al. (*2001); Cabrera (2001) and Cabrera and Perdomo (2003) who reported no effect of NaCl salinity on flower quality. Among different cultivars, 'Anjlique' 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.

This study revealed that tested cut rose cultivars are quite salt sensitive and with gradual increase in substrate salinity, yield and quality of the produce decreases. Therefore, either artificial substrates with good quality water should be used for cut rose production in areas where higher substrate salinity exists, or salinity should be lowered before growing cut roses. Higher salt concentrations affect metabolic activities by blocking the vascular tissues and increasing salt concentration in cells, which might be responsible for cell death which ultimately reduces growth, yield and quality (Hughes and Hanan, 1978; Ahmad, 2009). Moreover, among these cultivars, "Anjlique' could be the better option to be grown in areas with comparatively higher salt levels and 'Gold medal' and 'Kardinal' should not be grown in areas with higher salinity levels.

In summary, rose cultivars used in this study have proved quite salt sensitive and their growth, yield and quality is adversely affected with increasing substrate salinity level. Therefore, it can be concluded that roses should by grown on such soils which have less than 2.5 dS m^{-1} EC level. Among cultivars, 'Anjlique' was quite tolerant to comapratively higher salt concentrations than 'Kardinal' and 'Gold Medal' which advocates its suitability to be grown on such soils which are moderately saline. Preferably, saline soils should be avoided for cut rose production in order to get vigorous growth and higher flower production of superior quality.

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