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Effects of saline irrigation water applications on quality characteristics of freesia grown in greenhouse

Tuzlu sulama suyu uygulamalarının serada yetiştirilen frezya bitkisinin kalite özelliklerine etkisi

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ABSTRACT

This study was carried out in soilless culture to determine the effects of saline irrigation levels on flowering and flower quality of Freesia hybrids planted in a plastic greenhouse located in Bati Akdeniz Agricultural Research Institute between October 2005 and April 2006 under Mediterranean conditions. In the study, three freesia varieties, Oberon, Athena and Cordula corms were used. Four salinity levels, $EC_1 = 1.5 \text{ dS m}^{-1}$ (control), $EC_2 = 3.0 \text{ dS m}^{-1}$, $EC_3 = 4.5 \text{ dS m}^{-1}$ and $EC_4 = 6.0 \text{ dS m}^{-1}$, were applied using NaCl. It was found that saline irrigation water levels decreased the corm, cormel and flower yield, flower stem length and diameter, flower numbers and flower spike length in all freesia varieties studied. The threshold values for Athena, Oberon, and Cordula varieties were determined to be 2.7, 1.0, and 3.0 dS m^{-1} , respectively.

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ÖZ

Bu çalışma, 2005 yılı Ekim ve 2006 yılı Nisan ayları arasında Batı Akdeniz Tarımsal Araştırma Enstitüsü'nde, topraksız kültürde farklı tuzlu su düzeylerinin serada yetiştirilen Frezya süs bitkisinin çiçeklenme, çiçek kalitesi ve yumru verimi üzerine etkilerinin belirlenmesi amacıyla yürütülmüştür. Çalışmada, Oberon, Athena ve Cordula olmak üzere üç farklı çeşit kullanılmıştır. Dört farklı tuz düzeyi ($EC_1 = 1,5 \text{ dS m}^{-1}$ (kontrol), $EC_2 = 3,0 \text{ dS m}^{-1}$, $EC_3 = 4,5 \text{ dS m}^{-1}$ ve $EC_4 = 6,0 \text{ dS m}^{-1}$) NaCl kullanılarak sağlanmıştır. Tuzlu sulama suyu uygulamalarının tüm Frezya çeşitlerinde yumru, yumrucuk, çiçek verimi, çiçek sapı uzunluğu, çiçek sapı kalınlığı, çiçek sayısı ve başak uzunluğunu azalttığı belirlenmiştir. Tuzluluk eşik değeri Athena, Oberon ve Cordula frezya çeşitleri için sırasıyla 2,7, 1,0 ve $3,0 \text{ dS m}^{-1}$ olarak belirlenmiştir.

1. Introduction

Salinity is one of the most severe environmental factors limiting the productivity of agricultural crops. It is inevitable that the salt is accumulated in the soils when salty water is applied. Soil and water that contain salt naturally, causes problems in crop production.

In protected cultivation, intensive fertilizers and chemicals used for nutritional purposes and irrigations practiced unconsciously causes salt accumulation in the root zone resulting decrease in quality and quantity of production (Quamme and Stushnoff 1983; Sevgican 1999; Sonneveld et al. 1999).

Because the water resources over the world are not evenly distributed and can not be easily accessible during growing period, irrigation is necessary to get the best quality and

quantity in agriculture. The irrigation water contains soluble salts. The amount and kind of salts in water is important to determine its suitability for irrigation.

Decreasing and pollution of natural water resources gradually as a result of global warming force growers to use marginal quality waters in irrigated agriculture. Wrong irrigation applications, especially in areas where drainage problems exist, increase salinity levels which cause decrease in crop production and loose of soil productivity (Villora et al. 2000).

Generally, annual ornamental and vegetable plants are more sensitive to salt level than that of the perennial plants. Salinity creates irreversible harms in the growth and development of annual plants and restricts agricultural production (Maas 1984;

Sonneveld and van der Burg 1991; Sonneveld et al. 1999). Saline irrigation water causes decrease in crop yield, length of root, stem, shoot, leaf area, leaf number, fresh and dry weight, chlorophyll amount and change in color and physical appearance (Munns and Termaat 1986; Rhoades et al. 1992). Plants are affected in a different way by amount and kind of salt depending on their growth and development stage. Salinity has also different effects on plant organs. For example plant leaves are more sensitive than that of the plant roots (Hannah 1998).

In ornamental crops, plant length, flower number per plant, flower and shoot length, fresh and dry weights tend to decrease as salinity level increase. Kandeel et al. (1999), pointed out that as Na, Ca and Cl content increased in growing media, N, P and K content in flower and roots is decreased. On the other hand, ion toxicity and water deficit in old leaves and carbohydrate deficit in young leaves was observed when plant was exposed to salt stress for a long time (Kotuby-Amacher et al. 1997; Sonneveld et al. 1999; Picchioni and Graham 2001).

Studies carried out over the last thirty years on the tolerance of many vegetable crops to saline irrigation water showed that, many crops can be commercially cultivated with saline water under suitable irrigation program and crop management, and that quality characteristics in some of the crop species can even be improved (Mizrahi and Pasternak 1985; Pasternak 1987; Blaylock 1994; Sivritepe 2000; Esitken and Pirlak 2002; Ozturk 2002; Tuzel 2002; Blanco and Folegatti 2002; Kadayifci et al. 2004).

The effects of saline irrigation on ornamental plants have been investigated to a much lesser extent because ornamentals are normally irrigated with high quality water. The few studies were carried out in ornamental plants (François and Clark 1978; Ibrahim et al. 1991; Zurayk et al. 1993; Kuehny and Blanca 1998; Wang 1998; Sonneveld et al. 1999; Shillo et al. 2002; Akat et al. 2008). In this study, the effect of saline irrigation water on yield and quality characteristics of freesia grown in soilless culture in an unheated plastic greenhouse were investigated.

2. Materials and Method

The experiment was carried out between October 2005 and April 2006 in a plastic greenhouse located in Bati Akdeniz Agricultural Research Institute. The greenhouse used in the experiment is located at latitude of 36° 56' north, a longitude of 30° 53' east and an altitude of 28 m. The climate of the region is typically Mediterranean, i.e. mild and rainy in winter, dry and hot in summer.

To observe the effect of saline irrigation water levels on freesia corms and quality characteristics as well as to control the assigned salinity levels, the study was carried out in soilless culture, which was contained of perlite and peat mixture of 1:1 (v:v). Some characteristics of growing media used in the experiment were given in Table 1.

Table 1. Some characteristics of substrate used in the experiment.

Characteristic	Value
pH	6.9
CaCO ₃ (%)	1.6
Organic matter (%)	1.3
P (ppm)	11.6
K (ppm)	11.0
Ca (ppm)	910.0
Mg (ppm)	118.0
Na (ppm)	199.0

In this study, four different salinity levels of irrigation water (1.5 (control), 3.0, 4.5 and 6.0 dS m⁻¹) and three variety of freesia (Cordula, Athena and Oberon) were used. Irrigation salinity levels formed by main plots were designed according to randomized block design whereas varieties were designed as sub-plots. Thus, 4x3 split plots were applied and each treatment was replicated three times in the experiment (Gomez and Gomez 1984).

The varieties, athena having white colour flowers, cordula having yellow colour flowers and oberon having red colour flowers, used in the experiment have single-fold flower, uprighted leaf structures, long spike length and high number of spikes (Seyidoglu and Menguc 2002).

Three freesia corms having 4-6 cm perimeter and number size 3 were used. The corms were taken out of the cold storage room and were treated for 45 minutes with a Captan (0.4 %) + Benomyl (0.2 %) solution against fungal diseases just before planting (Ozcelik and Yelboga 1991).

Freesia corms were planted at a depth of 5 cm on 10 x 10 cm intervals in the growing beds having size of 0.2 x 0.2 x 10 m already filled with perlite and peat mixture. Thus 36 plots in total were formed, each of them containing 10 freesia corms. A 0.5 m wide walking spaces was left between growing beds.

For macro element stock solution used in the experiment, 8.5 kg Potassium nitrate, 2.5 kg Monoammonium Phosphate, 3.5 kg Amonium Nitrate and 0.3 kg Sequestrin were added in a tank of 200 L in volume. Micro element stock solutions were prepared by adding 116 g Borax, 68 g Manganese Sulphate, 60 g Zinc Sulphate, 8 g Copper Sulphate and 5 g Sodium Molybdat in another tank of 10 L in volume. The prepared stock solutions were used in irrigation practices for a balanced nutritional level in each treatment. Two liters of macro and one liter of micro stock solutions were added in irrigation water having EC value of 0.7 dS m⁻¹ to form control irrigation application whose EC value is 1.5 dS m⁻¹ (EC₁).

In order to obtain irrigation water having higher EC values (EC₂=3.0, EC₃=4.5 and EC₄=6.0 dS m⁻¹), 1400, 2200 and 2800 g m⁻³ NaCl were added in water having EC of 1.5 dS m⁻¹ (EC₁, control application). EC values were measured and adjusted to 25°C using a conductivity meter (Hanna Inst. HI8633).

The plants were irrigated once a week for one hour by a drip irrigation system having dripper discharging of 2 L h⁻¹ at a pressure of 0.1 MPa. So, each plant received about two liters of water with a constant leaching fraction of 15 %.

During the experiment, flower stem length (the length between cutting point and the tip of the last flower, cm), flower stem diameter (the diameter measured in the middle of stem, mm), spike length (the length between the first and last flower, cm), number of flower per spike (flower spike⁻¹) on harvested flower stems at each harvest, and yield (total number of harvested flower stems per plant during growing season), were determined. Also, the number of cormel (cormel corm⁻¹) and number of corm (corm plant⁻¹) were recorded at the end of the experiment. Variance analyses were applied to data obtained and Duncan's multiple range test was used to compare the averages (Gomez and Gomez 1984).

Relative flower yield as a function of irrigation water salinity is determined based on the equation ($Y_r = 100 - b(EC_w - a)$) given by Maas (1984).

3. Results and Discussion

The results with respect to flower yield and quality of freesia varieties together with statistical analysis are presented in Table 2. Considering the interactions, it was found that corm yield, flower yield, spike length, flower stem length, flower stem diameter and flower number per plant in salinity levels were statistically different at $P < 0.05$ whereas cormel yield was statistically different at $P < 0.01$. No difference was found for number of flowers per spike for interactions (Table 2).

The highest flower yield was obtained in Athena variety (4.5 flower plant⁻¹) in EC₁ while the lowest flower yield was obtained in Oberon variety (2.2 flower plant⁻¹) in EC₂ treatment (Table 3, Fig. 1a). Flower numbers per plant was decreasing with increasing salinity levels. Comparing the varieties, it is seen that Oberon variety is the most sensitive to salinity followed by Cordula and Athena varieties.

The flower stem length, flower stem diameter, spike length and flower numbers per spike are presented in Table 3 and Figure 1b, c, d, e.

While the longest flower stem length and spike length were obtained in Cordula variety (39.5 cm; 8.7 cm) in EC₁ treatment, the shortest flower stem and spike length were obtained in Cordula and Oberon variety (21.0 cm; 5.5 cm) respectively, both in EC₄ treatment (Table 3). In this study, it was determined that increasing salinity levels caused a decrease in flower stem length.

On the other hand, the thickest flower stem diameter was found in Oberon variety (4.3 mm) in EC₁ treatment, the thinnest flower stem diameter was found in Cordula varieties (3.2 mm) in EC₄ treatment (Table 3).

The highest flower numbers per spike was obtained in Cordula variety (10.1 number per spike⁻¹) in EC₁ treatment, whereas the lowest flower number per spike was obtained in Cordula variety (6.7 number per spike⁻¹) in EC₄ treatment. Increasing salinity levels caused a decrease in flower stem length, flower stem diameter, spike length and flower numbers per spike.

The highest corm and cormel yield were obtained in Athena variety in EC₁ (3.2 corm plant⁻¹ and 10.1 cormel corm⁻¹, respectively) while the lowest were obtained in Oberon variety in EC₄ (1.6 corm plant⁻¹ and 2.9 cormel corm⁻¹) (Table 3). Generally, corm and cormel yield were decreased as salinity levels increased excluding Cordula and Oberon varieties in EC₂ levels where the yield is increased and then decreased depending on higher salinity levels (Figure 2a,b).

In a study where saline water irrigation effect on corm weight and number of cormel was investigated, Shillo et al. (2002) reported also that there was no direct correlation to

increasing salinity levels in hippeastrum hybridum.

Saline irrigation water reduces the ability of the corm's root hairs to take up water. Between irrigations, as the soil moisture decreases, the salts in the soil solution concentrate to between two and five times their initial value in the soil water. This causes an increase in the osmotic pressure of the soil solution, which makes it more difficult for the plant roots to extract water and plant nutrients from the soil. Decreasing number of corm and cormel numbers due to irrigation with saline water is usually as a result of the osmotic stress caused by the total concentration of salts rather than due to specific ions (Bresler et al. 1982; Wang 1998; Sonneveld et al. 1999; Shillo et al. 2002).

Relative flower yield as a function of irrigation water salinity is shown in Figure 3 using the equation $Y_r = 100 - b(EC_w - a)$ (Maas, 1984). The estimated slope (b) for Athena, Oberon and Cordula is 8.5, 9.8 and 11.8, respectively. The threshold value (a) for Athena, Oberon, and Cordula was determined as 2.7, 1.0, and 3.0 dS m⁻¹, respectively. Assuming above mentioned b and a values, the relative flower yield can be estimated as zero when the electrical conductivity of irrigation water for Athena, Oberon, and Cordula is 14.5, 10.6, and 11.4 dS m⁻¹, respectively.

The decrease of measured vegetative parameters can be explained by the fact that increased level of salinity inhibits water uptake and crop nutritional elements from soil via roots. As explained in the materials and method section, the required salinity levels were prepared by adding NaCl in to stock solutions of 1.5 dS m⁻¹, resulting higher concentrations of Na⁺ and Cl⁻ ions in soil water. Higher concentrations of Na⁺ and Cl⁻ ions are hindering especially uptake of K⁺, Ca⁺⁺, NO₃⁻ ions and break down ion balance. Salinity reduces root development, water uptake as well as transpiration and respiration which results in perished hormonal balance, altered photosynthesis rate, decreased nitrate uptake, and cell growth. Overall, plant response to the above mentioned reduced physiological conditions occurs in lower flower yield and flower numbers per spike, shorter flower stem length and spike length and thinner flower stem diameter (Francois and Clark 1978; Robinson et al. 1983; Ibrahim et al. 1991; Zurayk et al. 1993; Baas et al. 1985; Hannah 1998; Kuehny and Blanca 1998; Wang 1998; Alarcon et al. 1999; Sonneveld et al. 1999; Wahome 2000; Shillo et al. 2002; Paradiso et al. 2003; De Lucia et al. 2003; Grieve et al. 2005).

4. Conclusions

In the present study, it was found that the salinity levels applied had effects on all of the characteristics of flower quality and yield. The highest quality characteristics were obtained from control treatment (EC₁=1.5 dS m⁻¹), followed by EC₂, EC₃,

Table 2. Variance analysis results with respect to yield and flower quality of freesia.

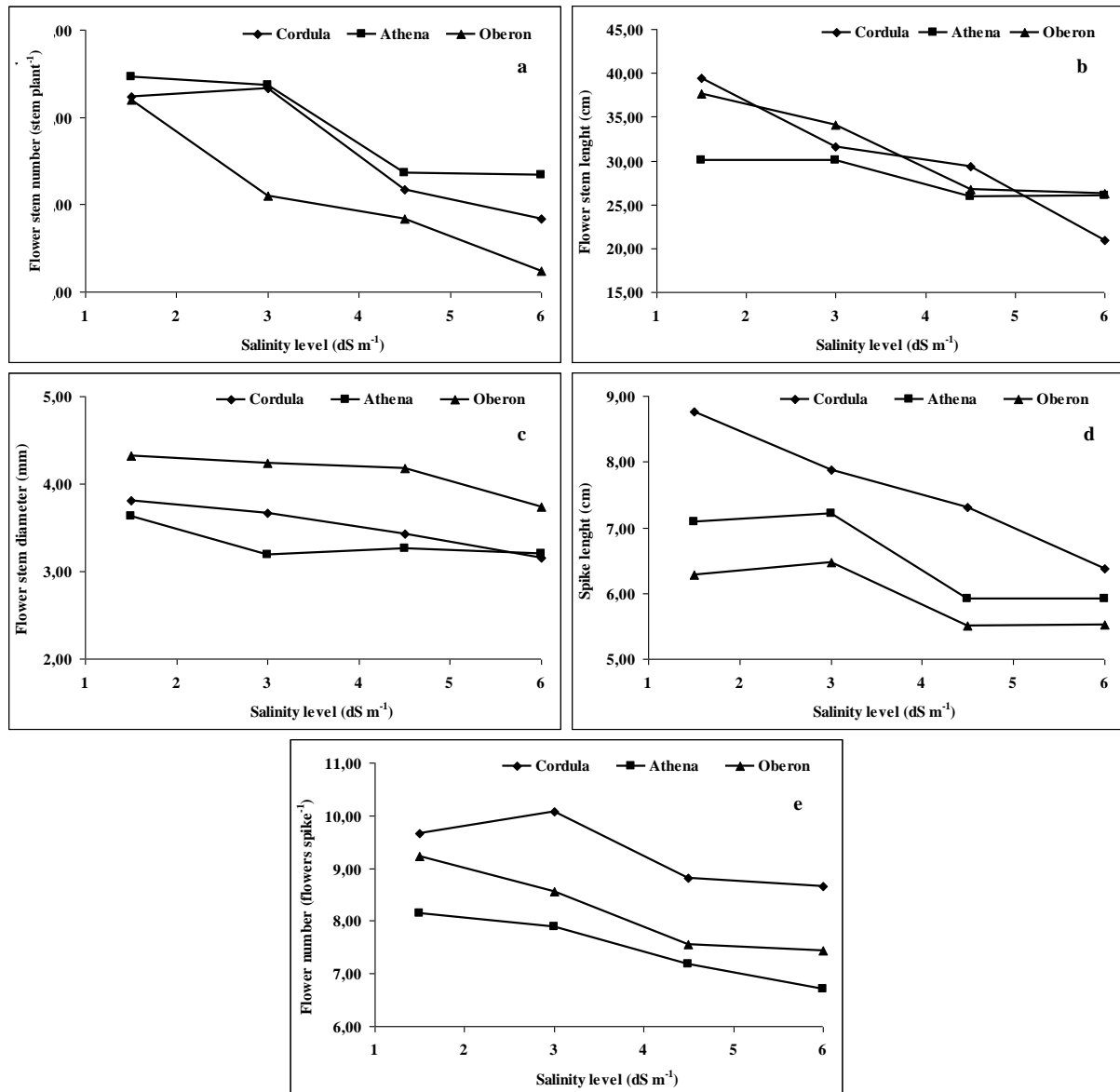
Source of variation	df	Harvested Flower stem number (stem plant ⁻¹)	Flower stem length (cm)	Flower stem diameter (mm)	Spike length (cm)	Flower number (flower spike ⁻¹)	Corm yield (corm plant ⁻¹)	Cormel yield (cormel corm ⁻¹)
Replication	2							
Varieties (V)	2	**	*	**	**	**	**	**
Error (V)	4							
Salinity (S)	3	**	**	**	**	**	**	**
V x S	6	*	*	*	*	NS	*	**
Error (V x S)	18							
Total	35							

NS: Not Significant; *, Significant at $P < 0.05$; **, Significant at $P < 0.01$.

Table 3. The average values of yield and flower quality characteristics in salinity levels and varieties.

Variety	Salinity level	Harvested Flower stem number (stem plant ⁻¹)	Flower stem length (cm)	Flower stem diameter (mm)	Spike length (cm)	Flower number (flower spike ⁻¹)	Corm yield (corm plant ⁻¹)	Cormel yield (cormel corm ⁻¹)
Cordula	EC ₁	4.23 ab ^z	39.48 a	3.81 bd	8.75 a	9.67 ab	2.10 df	7.3 cd
	EC ₂	4.33 ab	31.63 bd	3.67 df	7.87 b	10.07 a	2.63 bd	6.5 de
	EC ₃	3.17 cd	29.37 cd	3.43 df	7.31 bc	8.81 cd	2.33 ce	5.8 e
	EC ₄	2.83 de	20.96 e	3.15 f	6.38 dg	8.67 cd	2.03 ef	5.3ef
Athena	EC ₁	4.47 a	30.11 cd	3.63 df	7.08 be	8.15 df	3.20 a	10.1 a
	EC ₂	4.37 ab	30.10 cd	3.19 f	7.22 bd	7.89 eg	3.13 ab	8.8 ab
	EC ₃	3.70 bc	25.85 de	3.27 ef	5.92 fg	7.18 gh	2.47 ce	8.6 bc
	EC ₄	3.23 cd	26.04 de	3.20 f	5.92 fg	6.70 h	2.30 ce	7.7 bd
Oberon	EC ₁	4.20 ab	37.65 ab	4.31 a	6.28 eg	9.22 bc	2.23 ce	3.9 fg
	EC ₂	3.10 cd	34.06 ac	4.23 ab	6.47 cf	8.55 ce	2.77 ac	5.8 e
	EC ₃	2.83 de	26.78 ce	4.18 ac	5.52 g	7.56 fg	2.07 df	4.0 fg
	EC ₄	2.23 e	26.22 de	3.73 ce	5.50 g	7.44 fg	1.60 f	2.9 g

^zIn columns, different letters show different means according to Duncan test results at 5% confidence interval.

**Figure 1.** The effects of saline irrigation levels applications on flower stem number (a) and flower stem length (b), flower stem diameter (c), spike length (d) and flower number (e).

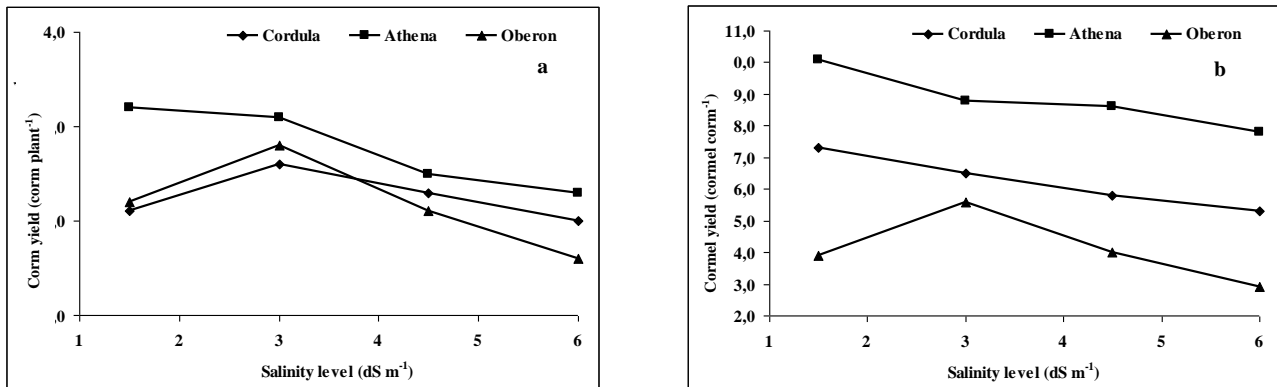


Figure 2. The effects of saline water irrigation applications on corm (a) and cornel (b) yield.

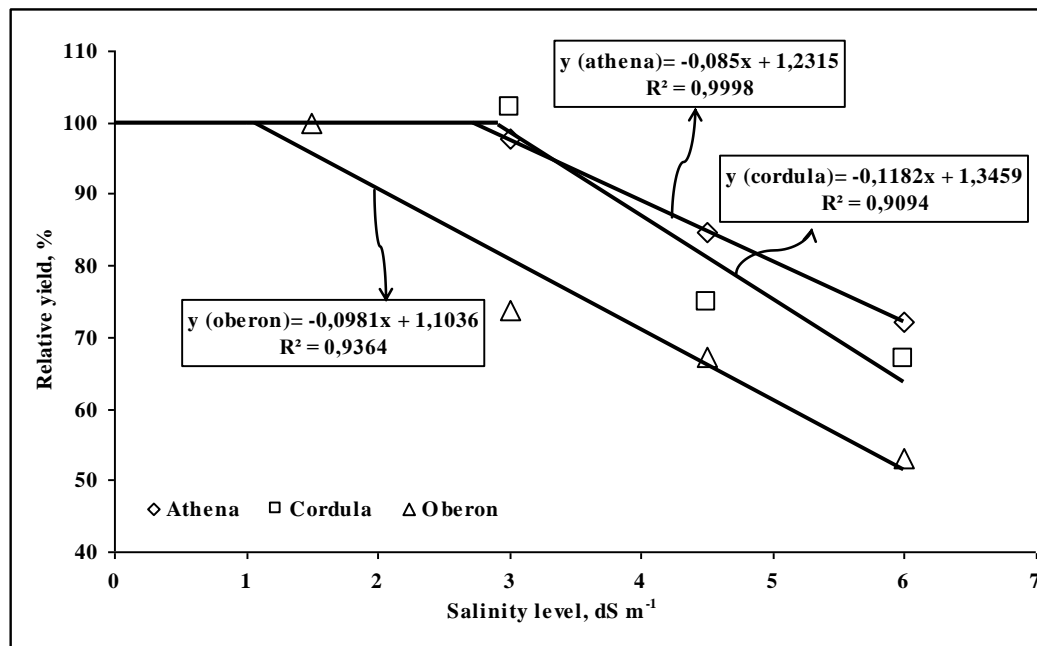


Figure 3. Relative flower yield of freesia varieties as a function of irrigation water salinity.

and EC₄.

Based on the results obtained from this experiment, it can be concluded that salinity threshold levels for cut freesia flower cultivation grown in soilless culture can be given as 3.0 dS m⁻¹ for Athena and Cordula varieties and 1.0 dS m⁻¹ for Oberon. Higher levels of saline irrigation water applications would reduce yield and other quality characteristics.

Taking into consideration of flower stem length and flower stem diameter in salinity treatments, it is seen that the most sensitive variety was found to be Oberon. However, the highest yield was obtained from Athena variety when number of corm and cornel was taken into the considerations.

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