**THE EFFECT OF CHLORIDE AND BICARBONATE LEVELS IN
IRRIGATION WATER ON NUTRITION CONTENT, PRODUCTION
AND QUALITY OF CUT ROSES 'MERCEDES'**

M. FERNÁNDEZ FALCÓN, C.E. ALVAREZ GONZÁLEZ, V. GARCÍA and
J. BÁEZ

*Consejo Superior de Investigaciones Científicas, Centro de Edafología y Biología
Aplicada de Tenerife, Apartado de Correos s/n, La Laguna, Tenerife, Canary
Islands (Spain)*

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Consejo Superior de Investigaciones Científicas, Centro de Edafología y Biología Aplicada de Tenerife, Apartado de Correos s/n, La Laguna, Tenerife, Canary Islands (Spain)

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ABSTRACT

Fernández Falcón, M., Alvarez González, C.E., García, V. and Báez, J., 1986. The effect of chloride and bicarbonate levels in irrigation water on nutrition content, production and quality of cut roses 'Mercedes'. *Scientia Hortic.*, 29: 373-385.

Irrigation with chlorinated (Cl^-) and bicarbonated (HCO_3^-) water, the main salts being NaCl and NaHCO_3 , respectively, was used to study the effect of Na^+ , Cl^- and HCO_3^- concentrations on the yield of good-quality cut roses from 'Mercedes' grafted on the rootstock *Rosa canina* 'Inermis'.

All treatments lowered the number of good-quality roses compared with irrigation with available water (control). The smallest number of flowers/plant (64% of control) was obtained with 13.6 mmol l^{-1} Cl^- ; water with 7.8 mmol l^{-1} Cl^- and 6.8 mmol l^{-1} HCO_3^- gave 79.6 and 78.6% flowers/plant of control, respectively. Concentrations of Na^+ , Cl^- and HCO_3^- in the soil and Na^+ and Cl^- in the leaves, when higher than normal (control), affected both the total number and the quality of the flowers produced.

Keywords: bicarbonate; chloride; nutrition; production; rose; sodium.

Abbreviations: EC = electrical conductivity. SAR = sodium adsorption ratio.

Abbreviations for treatments:

Control = available water = 2.60 mmol l^{-1} Cl^- and 3.52 mmol l^{-1} HCO_3^- ;

Cl-1 = 1st chloride treatment = 7.80 mmol l^{-1} Cl^- ;

Cl-2 = 2nd chloride treatment = 13.60 mmol l^{-1} Cl^- ;

B-1 = 1st bicarbonate treatment = 6.82 mmol l^{-1} HCO_3^- ;

B-2 = 2nd bicarbonate treatment = 9.56 mmol l^{-1} HCO_3^- ;

INTRODUCTION

When cultivating rose bushes for the production of cut flowers, the salinity of the irrigation water is a very important aspect, since it often constitutes a limiting factor in obtaining high yields. Hence water quality is one of the

principal factors to be taken into account when establishing a plantation. Many investigations have been carried out on the effect of the salinity of irrigation water on yields. McCall et al. (1961), working with 'Better Times' roses, found a marked decrease in production when the EC of the irrigation water rose from 1.0 to 1.5 d S m⁻¹. Hughes and Hanan (1978) found that production of 'Forever Yours' was considerably reduced when the EC of the water exceeded 1.8 d S m⁻¹. Fernández Falcón (1983), using salinized water, found a marked decrease (up to 50%) in the quality of flowers of 'Sonia' when the EC of the saturation extract reached values of 3.2 d S m⁻¹.

Apart from its detrimental effect on plant growth, high sodium levels in soil cause unfavourable effects on the physical properties of that soil (McGeorge and Breazeale, 1938). Moreover, its antagonistic effect on K uptake (Pereira and Westerman, 1978; Divate and Pandey, 1981) as well as on Ca and Mg uptake (Bower and Wadleigh, 1949) is well established.

Anionic composition of irrigation water, particularly of the Cl⁻ and HCO₃⁻ ions, plays an important role in plant growth. High level of chlorides in the soil increase its salinity level and consequently reduce yield (Hughes and Hanan, 1977). The hazard of sodification increases in water with high CO₃²⁻ and HCO₃⁻ concentrations which raise the SAR value. Moreover, high HCO₃⁻ concentrations in irrigation water reduce the Ca and Mg content of the soil extract (Sonneveld and Van den Ende, 1975; Garg and Garg, 1980), and affect Fe uptake by the plant (Agarwala and Mehnotra, 1978), thus decreasing the development of the plant and unbalancing the absorption of nutrients (Paliwal et al., 1978; Sonneveld, 1979).

In the present study, we tried to obtain quantitative data on the effect of Na⁺, Cl⁻ and HCO₃⁻ concentrations in the irrigation water on the production and flower quality of 'Mercedes' roses.

MATERIALS AND METHODS

The trial was carried out in a plastic greenhouse with *Rosa* hybrid 'Mercedes' grafted on *R. canina* 'Inermis'. The roses were grown in 200-l containers each of 0.5 m² surface area and containing 4 rose plants.

The soil used had the following characteristics; 300 g clay kg⁻¹ soil; 440 g silt kg⁻¹ soil; 260 g sand kg⁻¹ soil. The chemical analysis was as follows:

pH	EC (d S m ⁻¹)	Exch. Na (mmol l ⁻¹)	Solubles ions (mmol l ⁻¹)					
			Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	Cl ⁻	HCO ₃ ⁻
5.9	2.3	9.99	5.80	0.51	26.0	20.0	5.0	1.70

The roses were transplanted in September 1983, 6 months after grafting, and irrigation treatments began in March 1984. Three levels of chloride,

control, Cl-1 and Cl-2, and three levels of bicarbonate, control, B-1 and B-2, were established in the irrigation water. Each level was applied to 3 containers, each holding 4 plants. The solutions were applied by drip irrigation, 3 times per week. One control (irrigation with available water) was used for all treatments. Table I gives the characteristics of the available water (control) and the characteristics of the solutions used for the treatments, which are quite common in Canary Island irrigation procedures. The soil was leached once a month by increasing the time of drip-irrigation until drainage water was seen leaking from the container.

TABLE I

Chemical characteristics of the water used in the irrigation treatments

Treat- ment	pH	EC (25° C, d S m ⁻¹)	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	SO ₄ ²⁻	Cl ⁻
			(mmol l ⁻¹)							
Control	8.4	7.5	2.16	4.96	5.65	0.64	0.64	3.52	5.24	2.60
Cl-1	8.2	13.0	2.24	4.88	10.00	0.63	0.80	3.50	5.92	7.80
Cl-2	8.4	18.0	2.56	4.56	16.09	0.64	0.80	3.44	5.20	13.60
B-1	8.7	10.5	2.48	4.48	9.70	0.64	1.36	6.82	5.40	2.64
B-2	8.9	13.9	2.40	4.56	12.94	0.64	2.16	9.56	4.92	2.64

In addition, N (37.5 g year⁻¹), P (3.28 g year⁻¹) and K (25 g year⁻¹) were added as fertilizers to each container, including the controls. Soil and leaf samples were taken in May, July and September 1984. Two soil sub-samples from each container, were taken by a worm-type auger from 30 cm depth, forming one composite sample for each treatment. The leaf samples consisted of the first two 5-leaflet leaves and were taken when the flower bud showed from 1 to 3 separated sepals (García et al., 1984).

The mean temperatures and relative humidities registered in the greenhouse were as follows:

	Air temperature (°C)		Relative humidity (%)
	Minimum	Maximum	
Autumn	17.6	37.3	66
Winter	14.4	33.3	77
Spring	18.2	38.2	69
Summer	20.5	40.3	55

Flowers were cut at the stage generally taken by commercial growers (most of the sepals separated). They were classified according to their stem length. We considered a good-quality flowers to be those whose stem length was greater than 40 cm.

Analytical techniques

Soil. — Exchangeable Na, K, Ca and Mg were extracted with a solution of 1 N ammonium acetate at pH 7, with a ratio of soil to extractant of 1:5, and shaking for 30 min. Sodium and K in the extract were determined by flame photometry and Ca and Mg by atomic absorption spectrophotometry. For available P, the method of Olsen et al. (1954) was followed, and P was determined in the extract by colorimetry according to the Murphy—Riley method modified by Watanabe and Olsen (1965). Conductivity was measured in the saturation extract. Soluble ions were determined in the saturation extract by the following techniques: Na and K by flame photometry; Ca and Mg by atomic absorption spectrophotometry; CO_3^{2-} and HCO_3^- by the Mohr method (Rodier, 1981); Cl^- by titration with silver nitrate (Chapman and Pratt, 1961).

Leaves. — Minerals in leaves were analyzed by the dry-ash method (Chapman and Pratt, 1961). The extraction was made by treating the ash with 6 N HCl except in the case of Cl^- , in which the extraction was made with hot water. The levels of P and the K, Ca, Mg, Na and Fe cations were determined in the extract. The concentrations of K, Ca, Mg, Na and Fe were determined by atomic absorption spectrophotometry. Phosphorus was determined by colorimetry according to the vanadate—molibdate method (Chapman and Pratt, 1961) using a "Bausch and Lomb" spectronic 20 meter. Chloride ions were determined in the aqueous extract by titration with silver nitrate according to Piper (1947). Nitrogen was determined by the Kjeldahl method (Cottenie, 1980).

RESULTS AND DISCUSSION

Soil analysis. — Table II summarises the results of the chemical analysis of the soil samples in May, July and September, respectively, for each of the treatments used.

The reduction in pH of the original soil (5.9) after fertilization and irrigation with solutions having pH of 8.2–8.9 (Table I), as observed in the samples taken in July (Table II), may be explained by the heavy fertilization with ammonium sulfate, equivalent to 3571 kg ha^{-1} , which is quite normal for fertilization of roses in the Canary Islands. It should be noted that Pierre (1927) observed diminutions of more than 0.5 units of pH when he applied up to 840 kg of ammonium sulfate per ha in acid soils. Nevertheless, the soil pH observed throughout the trial fell within the range shown by 46% of the soils used for rose cultivation in Tenerife (Fernández et al., 1984).

The exchangeable cations, with the exception of Na, do not show clear differences between the saline and control treatments (Table II). Exchangeable Na values were clearly higher in the chlorinated and bicarbonated treat-

TABLE II

Chemical analysis of soils following treatments

Treat- ment	pH	Exchan- geable Na ⁺ (mmol l ⁻¹)	Solubles ions (mmol l ⁻¹)							EC (25° C, d S m ⁻¹)
			Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	Cl ⁻	CO ₃ ²⁻	HCO ₃ ⁻	
May										
Control	4.54	22.13	10.04	1.68	18.40	19.60	6.00	0.00	0.50	2.70
Cl-1	4.34	24.38	17.87	1.92	22.80	28.80	14.00	0.00	0.50	3.80
Cl-2	4.35	31.00	24.30	1.72	32.00	25.20	22.40	0.00	0.50	4.55
B-1	4.51	22.44	15.22	2.82	20.00	22.00	7.80	0.00	0.80	3.20
B-2	4.67	24.38	18.69	1.68	28.00	23.20	9.40	0.00	0.90	3.70
July										
Control	5.01	15.50	11.74	2.17	24.00	30.00	9.20	0.00	0.80	3.70
Cl-1	4.68	26.62	21.30	2.56	42.00	48.00	27.40	0.00	0.80	6.05
Cl-2	4.68	31.01	24.78	2.69	37.20	42.00	33.40	0.00	0.90	6.50
B-1	5.02	17.75	16.96	3.32	37.60	35.20	12.20	0.00	2.12	5.00
B-2	5.01	42.13	22.17	2.17	31.20	37.00	12.00	0.00	2.20	5.15
September										
Control	4.80	17.75	15.22	2.56	24.00	33.20	9.20	0.00	0.85	4.20
Cl-1	4.93	29.58	24.05	1.98	54.00	53.20	33.00	0.00	1.00	6.00
Cl-2	4.80	37.74	34.35	2.81	33.60	42.40	36.40	0.00	1.00	7.65
B-1	4.95	24.38	23.91	3.32	39.20	37.60	12.80	0.00	1.30	5.85
B-2	5.00	33.25	31.74	2.56	44.00	35.60	13.00	0.00	1.60	6.90

ments than in the control treatment. There are marked differences between exchangeable Na in the chlorinated treatments. In the September sampling, exchangeable Na in Cl-1 is 29.58 mmol l⁻¹ and that for Cl-2 is 37.74 mmol l⁻¹. This is also seen in the B-1 and B-2 treatments, which show exchangeable Na values of 24.38 and 33.25 mmol l⁻¹, respectively, while the corresponding value for the control is 17.75 mmol l⁻¹. Soluble Na shows higher values in the saline treatments than in the control in the May and July samplings, and a notable increase was observed in September (from 8 to 19 mmol l⁻¹). These increases are a result of the amounts of Na involved in the chlorinated and bicarbonated treatments. Appreciable differences are also seen between the soluble Na content of treatments Cl-1 and Cl-2, which in the September sampling show values of 24.05 and 34.35 mmol l⁻¹, respectively. Treatments B-1 and B-2 have soluble Na values of 23.91 and 31.74 mmol l⁻¹, respectively.

Chlorination has a clear effect on the soil-soluble anions. The control value of 9.2 mmol l⁻¹ (September sampling) increased to 33.0 mmol l⁻¹ in Cl-1 and 36.4 mmol l⁻¹ in Cl-2. The Cl⁻ concentrations are positively correlated with exchangeable and soluble Na ($r=0.8769$, sig. > 1%, and $r=0.8770$, sig. > 1%, respectively), which was to be expected since the prin-

cial salt of the chlorinated treatments was NaCl. A positive correlation, significant at the 1% level ($r=0.7890$), is also found between the Cl^- concentrations and soluble Ca, which could be explained by the fact that Cl^- forms very soluble salts with Ca^{2+} producing CaCl_2 , so that the Ca concentration in the soil solution can increase at the expense of the exchangeable Ca.

Differences in HCO_3^- concentrations are observed between the bicarbonated and the control treatments. Treatment B-1 gives 1.30 mmol l^{-1} and Treatment B-2 gives 1.60 mmol l^{-1} as against 0.85 mmol l^{-1} for the control. These HCO_3^- concentrations are low in relation to what might be expected considering the treatments applied. This may be explained when we assume that the HCO_3^- ions are partly decomposed by the high concentration of H^+ in the soil (Lindsay, 1979).

As regards the electrical conductivities shown by the soil, appreciable differences are also observed between the saline treatments and that of the control which shows, for the September sampling, a EC value of 4.20 d S m^{-1} as against 6.00 and 7.65 d S m^{-1} for Treatments Cl-1 and Cl-2, respectively. These EC values are always higher in the chlorinated treatments because, as already stated, the HCO_3^- seems to be partly decomposed and barely contributes to soil salinity. Thus, while significant correlations are found between Cl^- and Na^+ against the EC ($r=0.9056$, sig. $> 1\%$, and $r=0.9020$, sig. $> 1\%$, respectively), this is not true for HCO_3^- .

Accumulation of soluble salts in the soil solution is observed throughout the different samplings dates (Table II), although the soil was leached once a month, as described in Materials and Methods

Foliar analysis. — Table III gives the results of chemical analysis of the leaf samples for each of the treatments used.

The effect that soil HCO_3^- has on K levels in the foliage should be stressed, since foliar K generally decreases in treatments with bicarbonated water. Ivanov and Ivanova (1976) also observed that increased soil HCO_3^- reduced K levels in the foliage of deciduous fruit trees.

A generalized chlorosis was observed in the bicarbonated water treatments, which is in agreement with the findings of Hughes and Hanan (1975, 1976, 1977, 1978) and Fernández Falcón (1983). Leaf Fe concentration is also lower in the bicarbonated water treatments, especially Treatment B-2, as against that of the control. The chlorosis may be due to Fe precipitation as carbonate salt during the irrigation period and also thereafter, since the level of HCO_3^- in the saturation extract was much lower than in the B-1 and B-2 solutions of irrigation water. Nevertheless, physiological disturbance in the iron metabolism caused by the bicarbonated ions, as suggested by Agarwala and Mehnotra (1978) for rice, cannot be ruled out.

The Cl^- in leaves of the chlorinated treatments ranged from 2.7 to 3.8 g kg^{-1} for Cl-1 and from 4.6 to 5.6 g kg^{-1} for Cl-2, which are markedly different from the controls (from 1.6 to 2.0 g kg^{-1}).

The levels of Na in the leaves were noticeably higher in both the chlo-

TABLE III

Chemical analysis of leaves following treatments

Treat- ment	N	K ⁺	Cl ⁻	Fe ²⁺	Na ⁺
	(g kg ⁻¹)			(mg kg ⁻¹)	
May					
Control	30.8	28.4	2.0	82	362
Cl-1	32.5	27.8	2.7	88	372
Cl-2	31.9	25.9	4.9	89	392
B-1	32.2	25.8	1.8	82	431
B-2	32.8	25.0	1.9	80	451
July					
Control	29.4	22.6	1.9	135	348
Cl-1	33.2	28.6	3.5	99	394
Cl-2	26.6	24.2	4.6	125	484
B-1	28.7	23.1	1.7	125	380
B-2	24.1	22.2	1.8	76	524
September					
Control	29.4	25.2	1.6	123	354
Cl-1	23.3	27.2	3.8	121	2040
Cl-2	20.3	22.8	5.6	132	4800
B-1	28.0	20.5	1.6	86	1100
B-2	28.0	22.4	1.7	99	2625

minated and the bicarbonated treatments as against the control. A negative correlation was found between Na and foliar N, significant at the 1% level ($r=-0.7279$), which confirms the observations made by Singh (1982).

Soil-plant relations. — The relationships found between exchangeable and soluble Na, soluble HCO_3^- , Cl^- and EC and plant nutrients are set out in Table IV.

The foliar N concentration is negatively affected by the presence of exchangeable and soluble Na in the soil. This is reflected in the negative correlations obtained, and confirms the findings of Singh (1982) for leaf Na and N. The concentration of leaf K seems to be influenced by soluble soil HCO_3^- , a negative correlation, significant at 2%, being found between them, which is similar to that obtained by Ivanov and Ivanova (1976).

As was to be expected, both exchangeable and soluble Na are correlated positively with leaf Na at significance levels of 5 and 0.1%, respectively. Furthermore, positive correlations are noted between soil Cl^- and EC as against the leaf Na, which is explained by the fact that the Cl^- in the irrigation water was supplied in the form of NaCl which, in turn, affects the soil EC, as we have already shown. Leaf Cl^- is positively correlated with soil Cl^- as well as its exchangeable and soluble Na and EC. These

TABLE IV

Correlation coefficients and regression equations between the results of foliar analysis and chemical characteristics of the soil

Leaf	Soil	Soluble ions			EC
		Exchangeable Na^+	Na^+	HCO_3^-	Cl^-
N		$y = -0.296X + 36.68^*$ $r = -0.583$ (5%)	$y = -0.334X + 35.71^*$ $r = -0.591$ (2%)		
K^+				$y = 24.25 - 3.54 \ln X^{**}$ $r = -0.7429$ (2%)	
Na^+		$y = 0.950 X^{1.699*}$ $r = 0.566$ (5%)	$y = 74.79 e^{0.10X^*}$ $r = 0.821$ (0.1%)		$y = 71.24X - 402.57^{***}$ $r = 0.7148$ (5%)
Cl^-		$y = -3.730 X^{1.506}^{***}$ $r = 0.9459$ (1%)	$y = 0.179X - 0.245^{***}$ $r = 0.9378$ (1%)		$y = 0.722X - 0.225^{***}$ $r = 0.8835$ (1%)

*All treatments.

**Sodium bicarbonate treatments plus control.

***Sodium chloride treatments plus control.

relationships were to be expected in view of the close interdependence of these soil chemical characteristics.

Production. — Table V gives the average production of flowers for the different treatments, as well as their quality. The average total production of flowers per plant varied from 35.08 (control treatment) to 22.42 (Treatment Cl-2). Moreover, the number of good-quality flowers (stem length greater than 40 cm) was between 14.50 and 6.83 cut flowers per plant for the treatments control and Cl-2, respectively.

TABLE V

Number of flowers per plant with different stem-length and total production of flowers after different treatments

Treatment	Stem-length (cm)				Total production		
	< 30	30-40	40-50	> 50	Number of flowers	Flowers* per plant	Good-quality flowers (= stem-length > 40 cm)**
Control	3.83	16.80	12.92	1.58	421	35.08 a	14.50 a
Cl-1	3.25	17.40	6.08	1.17	335	27.92 b	7.25 b
Cl-2	3.42	12.20	5.75	1.08	269	22.42 c	6.83 b
B-1	2.75	15.40	8.50	0.92	331	27.58 b	9.42 b
B-2	3.08	11.80	7.50	1.50	286	23.83 bc	9.00 b

Data followed by different letters are significantly different at $P < 0.01$.

*LSD = 5.45; ** LSD = 4.56.

The variance analysis (Table V) shows that there are differences, significant at the 1% level, between the total number of flowers/plant of the control as against the rest of the saline treatments. Treatment Cl-2 shows the smallest number of flowers and differs widely from the production obtained in Treatments Cl-1 and B-1. As regards the number of good-quality flowers per plant, the control treatment showed the greatest number in comparison with the rest of the treatments (significance 1%), while there are no differences between the saline treatments.

Table VI shows the effect of soil Na^+ , Cl^- and HCO_3^- ions and EC on rose production. Both exchangeable and soluble Na show negative correlations with the total number of flowers and with their quality, which both decrease. This was also observed by McCall et al. (1961), Bernstein et al. (1972), Hughes and Hanan (1976) and Singh (1982). Cl^- , HCO_3^- and EC (Fig. 1) are also negatively correlated with total flowers, confirming the findings of Yaron et al. (1969), Hughes and Hanan (1975, 1976, 1977, 1978) and Ishida et al. (1978). Although we observed a negative effect of EC on flower production, this effect seems mainly to be produced by the sodium, chloride and bicarbonate ions, since no correlation was observed

TABLE VI

Coefficient of correlation and regression equations between cut-rose production and some chemical characteristics of the soil

Production	Soil	Soluble ions			EC
		Exchangeable Na^+	Cl^-	HCO_3^-	
Total number of flowers					
		$y = 68.04 - 14.49 \ln X$	(a) $y = -0.771X + 39.37$	(a) $y = -27.40X + 48.93$	(a) $y = 55.91 - 22.59 \ln X$
		$r = -0.960$ (1%)	$r = -0.9960$ (5%)	$r = -0.9959$ (6%)	$r = -0.990$ (5%)
	(b)	$y = 73.55 - 15.75 \ln X$	(b) $y = -0.493X + 39.98$	(b)	$y = 58.69 - 19.04 \ln X$
		$r = -0.949$ (2%)	$r = -0.9881$ (10%)		$r = -0.843$ (10%)
Number of good-quality flowers (* stem > length 40 cm)		$y = -0.603X + 44.57$	(c) $y = 76.84 - 15.39 \ln X$	$y = -15.13X + 47.74$	(c) $y = 66.02 - 21.57 \ln X$
		$r = -0.953$ (1%)	$r = -0.999$ (0.1%)	$r = -0.9972$ (5%)	$r = -0.996$ (0.1%)
		$y = 34.16 - 8.83 \ln X$	(a)		$y = -3.91X + 23.43$
		$r = -0.941$ (2%)			$r = -0.886$ (5%)
		$y = 38.17 - 9.81 \ln X$	(b) $y = 28.15 - 6.18 \ln X$	(b) $y = -3.893X + 17.62$	(b) $y = -2.74X + 23.86$
		$r = -0.951$ (2%)	$r = -0.9955$ (6%)	$r = -0.998$ (2%)	$r = -0.968$ (1%)
	(c) $y = 40.72 - 9.44 \ln X$	(c) $y = 36.90 - 8.25 \ln X$	(c) $y = 26.97 - 5.62 \ln X$		$y = -2.05X + 21.95$
	$r = -0.910$ (5%)	$r = -0.861$ (6%)	$r = -0.998$ (1%)		$r = -0.869$ (6%)

(a) 1st sampling (May); (b) 2nd sampling (July); (c) 3rd sampling (September).

Fig. 1. Relationship between total yield (flowers per treatment, Table V) and the electrical conductivity of the soil (September, Table II).

between flower production and soluble ions other than Na^+ , Cl^- and HCO_3^- .

The negative effect of leaf Na on the total number of flowers stands out, as was also noted earlier by Ishida et al. (1978) and Fernández Falcón (1983), showing significant correlations ($r = -0.8830$, sig. > 5%, and $r = -0.9620$, sig. > 2%, for the July and September samplings, respectively). The same was found with Cl^- ($r = -0.9995$, sig. > 2%, and $r = -0.9998$, sig. > 1%, for the July and September samplings, respectively), as was also observed by these authors. The depressive effect of Na on the production and quality of the cut roses could be due to its toxic effect, as was indicated by Bharwaj (1961).

CONCLUSIONS

Soil HCO_3^- has a negative effect on the foliar levels of K. This interaction is interesting since the effect of the bicarbonate ions in the soil on the foliar nutrients in roses has rarely been studied.

Soil Na, Cl^- , HCO_3^- and EC have a negative effect on the production and quality of cut roses. Flower quality and production were reduced when the HCO_3^- concentration in the irrigation water was 6.82 mmol l^{-1} or higher, and the EC was 10.5 d S m^{-1} or higher. A similar tendency was observed

when Cl^- concentrations in the irrigation water showed values of 7.80 mmol l^{-1} or higher and Na was over 9.69 mmol l^{-1} .

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