COLORADO FLOWER GROWERS ASSOCIATION, INC.

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EFFECTS OF INCREASED SOLUBLE SALT CONCENTRATIONS ON CARNATION GROWTH

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High soluble salt concentrations are often found in water from shallow irrigation wells (3). Calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), chloride (Cl^{-}), bicarbonate (HCO_3^{-}), and sulfate ($SO_4^{=}$) often exceed nutrient levels recommended for carnation growth (Table 1). Fertilizer addition to salty waters will result in an increased total concentration, and the nutrient ion ratios may be different from those recommended for less saline waters.

Increased concentrations of Na^{+}, ammonium (NH_4^{+}), and Cl^{-} have been shown to significantly decrease growth of carnations (2, 4, 6). Such ions may decrease plant growth by competing with more essential nutrients in metabolism or during absorption. Competition between positively and negatively charged ions has been found to occur in many plant species (1). The adverse effects of certain ions on carnation growth may be reduced by adjusting nutrient concentrations and ion ratios in the nutrient solutions.

The objectives of these studies were to determine:

1. Interactions among ions during absorption as nutrient solution concentrations and ion ratios varied.
2. Optimum ion ratios and concentrations in moderately saline and/or sodic waters.

Table 1. Average salt content of irrigation waters and current nutrient recommendations for carnations in Colorado (3, 4).

Ion	Irrigation water content		Recommendations	
	me/l	ppm	me/l	ppm
K	negligible	-	6	235
Ca	10	200	3	60
Mg	6	73	2	24
Na	14	322	-	-
NO_3	negligible	-	12	749
SO_4	12	576	2	96
H_2PO_4	negligible	-	1	97
Cl	4	142	-	-
HCO_3	8	488	-	-

[1]This article is one of a series of studies made by Kurt Schekel while earning the Ph.D. in Horticulture at CSU. Kurt's present address is Washington State University.

MATERIALS AND METHODS

The research consisted of two studies: (1) ion competition and interactions during carnation uptake, planted July 20, 1969 and harvested December 16, 1969; and (2) the effect of high concentrations of individual saline ions and sodium on carnation growth and yield, planted November 10, 1969 and harvested April 28, 1970.

White Sim carnation cuttings were rooted in the usual manner at the CSU Research Greenhouses. Two rooted cuttings were planted in an 8-inch plastic pot containing gravel as the medium. The plants were pinched to six-leaf pairs per plant, then grown through the first flower crop, or approximately 6 months.

Nutrient solutions were applied in sufficient quantities at each irrigation to leach the growing medium and prevent salt build-up. Watering frequency was twice a day during the winter and increased to four times a day during the late spring, summer, and early fall. Nutrient concentrations are presented in Tables 2 and 3.

Solutions for Study 1 were to determine possible cation interactions during absorption from saline and/or sodic irrigation waters (Table 2). Solutions for Study 2 were formulated to maintain the same total concentration (-0.80 ± 0.05 atm) while individual ion concentrations were varied (Table 3). A concentration of -0.80 atm would represent that of a saline irrigation water (Table 1) to which only the deficient nutrients are added at recommended levels. A preliminary study showed carnation yield and quality decreased as nutrient solution concentration increased (5). In the following studies nutrient concentrations were maintained at levels which would be possible in the more saline irrigation waters. However, excessive concentrations were avoided.

Total fresh and dry weight yields of above-ground plant parts were recorded at the end of each study. Flower weights were also recorded as harvested and included in total plant yields. Tissue samples were taken and analyses determined by the CSU Soil Testing Laboratory. All tissue analyses are presented in milligram equivalents per kilogram dry matter (me/kg dm).

Table 2. Nutrient concentrations for the cation interaction study.[a] See Table 8 for conversion of me/1 to ppm.

	Nutrient Concentration							
Solu-tion	Ca me/l	K me/l	Mg me/l	Na me/l	NO_3 me/l	SO_4 me/l	Cl me/l	H_2PO_4 me/l
1	10	6	3	2	14	6.5	0.5	--[b]
2	10	8	3	2	14	8.5	0.5	--
3	10	10	3	2	14	10.5	0.5	--
4	10	12	3	2	14	12.5	0.5	--
5	10	6	3	8	14	12.5	0.5	--
6	10	8	3	8	14	14.5	0.5	--
7	10	10	3	8	14	16.5	0.5	--
8	10	12	3	8	14	18.5	0.5	--
9	4	4	3	8	14	4.5	0.5	--
10	4	6	3	8	14	6.5	0.5	--
11	4	8	3	8	14	8.5	0.5	--
12	6	6	1	0.5	12	1.0	0.0	0.5

[a]Four ppm of Fe as FeEDTA and 1 ppm B as H_3BO_4 were added to all solutions.

[b]Phosphorus was applied as superphosphate (44% P) at a rate of 2 lb/100 square feet growing area.

Table 3. Nutrient concentration for solutions in the individual ion study.[a]

	Nutrient Concentration							
Solu-tion	Ca me/l	K me/l	Mg me/l	Na me/l	NO_3 me/l	SO_4 me/l	Cl me/l	H_2PO_4 me/l
1	9	9	1.5	0.75	18	1.5	0	0.75
2[c]	9	9	1.5	0.50	12	2.0	0	--[b]
3	12	7	1.5	0.50	19	2.0	0	--
4	6	6	1.5	6.00	18	1.5	0	--
5	9	11	1.5	0.50	13	9.0	0	--
6	9	11	1.5	0.75	12	8.0	2.25	--
7	6	6	1.0	0.50	12	1.0	0	0.50

[a]Four ppm Fe as FeEDTA were added to solutions 1, 3-7; and four ppm Fe as EDDHA were added to 2.

[b]Phosphorus was applied as superphosphate (44% P) at a rate of 2 lb/100 square feet growing area.

[c]Six me/1 of HCO_3^- were added to this solution.

RESULTS AND DISCUSSION

At the relatively low nutrient concentrations used in these studies, ionic ratios and constituents of the nutrient solution are more critical than total concentration. This does not mean that the total nutrient concentration should be neglected. As low a total concentration as possible should be maintained while providing a complete nutrient solution.

Saline or sodium ions do not decrease carnation yield greatly if all other nutrients are present in adequate amounts (Table 4). Sulfate ions were least detrimental to carnation growth (Table 4). Carnations can exclude $SO_4^{=}$ ions effectively even against high concentration gradients (Table 5). The main effect of high $SO_4^{=}$ concentrations in the nutrient solutions was to increase the total concentration.

The amount of Na^+ in the tissue had a direct relationship to the concentration in the nutrient solution (Table 5). However, the presence of adequate K^+ in the solution reduced the level of Na^+ in the tissue (Table 6). With K^+ and Na^+ concentrations near a 1:1 ratio, Na^+ in the plant was reduced. A tissue Na^+ level of 137 me/kg dm, or less, produced satisfactory carnation growth when other nutrients were adequately supplied.

High Ca^{++} concentrations (10-12 me/1) in the nutrient solution tended to decrease carnation yield (Tables 5 and 7). Increasing the solution concentrations of K^+ or Na^+ lowered Ca^{++} tissue levels and did not improve yield (Table 7, Fig. 1). The combination of increased K^+ and reduced Ca^{++} in solution greatly reduced Ca^{++} tissue levels (Fig. 1). Competition of K^+ and Na^+ with Ca^{++} did not affect carnation yield in this study. However, problems may arise if the Ca^{++} concentration in the nutrient solution becomes excessively low.

Increasing the Cl^- content in the nutrient solution to 2 me/1 did not reduce carnation growth (Table 4). The presence of NH_4^+ increased tissue levels of Cl^-. The Cl^- ions were probably absorbed to some extent to balance the positive charge of NH_4^+ ions which were rapidly absorbed. No decreased yields

Table 4. The effect of increasing concentrations of individual ions on the total fresh carnation yield per plant.

Solution	Treatment	Total solution concentration	Yield
5	High sulfate	44.0	424 [a]
7	Check	27.0	409
6	High sulfate + chloride	44.5	405
1	1.5 x check	40.5	383
4	High sodium	39.0	368
2	High bicarbonate	40.0	366
3	High calcium	42.0	362

[a]Numbers followed by the same line are not significantly different.

Table 5. The relationship of solution Na^+ or $SO_4^{=}$ concentration to Na^+ or $SO_4^{=}$ levels in carnation tissue expressed as milligram equivalents per kilogram of dry matter. (See Colorado Flower Growers Bulletin 229 for nutrient concentrations.)

	Total concentration	Concentration in solution: Na^+		Concentration in solution: $SO_4^{=}$		Concentration in tissue me/kg dm	
Solution	me/l	me/l	ppm	me/l	ppm	Na^+	$SO_4^{=}$
5	108	2	46	4.0	192	22	98
6	58	16	368	16.5	792	283	133
7	120	47	1,081	47.5	2,280	348	136
8	306	140	3,220	140.5	6,744	565	126
9	616	295	6,785	295.5	14,184	1,131	109

Table 6. The effect of increasing K^+ solution concentration on the carnation tissue level of Na^+ expressed as milligram equivalents per kilogram of dry matter.

Solution	Na^+ solution concentration me/l	ppm	K^+ solution concentration me/l	ppm	Na^+ tissue concentration me/kg dm
12	0.5	12	6	235	26
1	2	46	6	235	46
2	2	46	8	313	44
3	2	46	10	391	41
4	2	46	12	469	38
9	8	184	4	156	137
5	8	184	6	235	96
6	8	184	8	313	98
7	8	184	10	391	85
8	8	134	12	469	80

Figure 1. Relationship between K^+ and Na^+ concentration in the nutrient solution and Ca^{++} levels in carnation tissue expressed as milligram equivalents per kilogram of dry matter. Sodium concentrations were held constant at 2 me/l for line A and 8 me/l for lines B and C. Calcium concentration was 10 me/l for lines A and B and 4 me/l for line C. Potassium concentration was increased in each series by the addition of K_2SO_4.

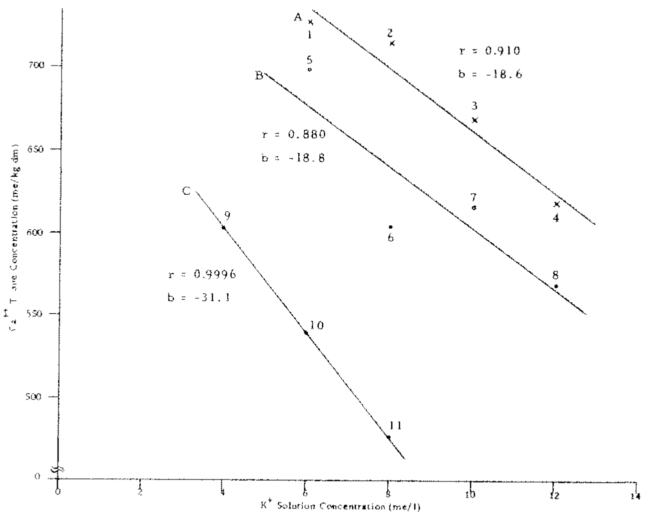

Table 7. The influence of solution concentrations of Ca^{++}, Na^+, and K^+ on carnation yield expressed as grams fresh weight per plant.[a]

Solution	Solution Ca^{++} concentration	Solution K^+ concentration	Solution Na^+ concentration	Yield
11	4	8	8	366[b]
3	10	10	2	361
9	4	4	8	361
12	6	6	0.5	361
5	10	6	8	350
2	10	8	2	344
7	10	10	8	344
8	10	12	8	343
10	4	6	8	343
1	10	6	2	337
4	10	12	2	334
6	10	8	8	323

[a]Three me/1 of Mg^{++} were in solutions 1-11, while 1 me/1 of Mg^{++} was in solution 12.

[b]Numbers followed by the same line are not significantly different.

were observed as the tissue Cl^- concentration increased. However, waters with Cl^- concentrations higher than 2 me/1 may decrease carnation growth, expecially if NH_4^+ ions are present in solution.

The presence of HCO_3^- appeared to have little effect on carnation growth (Table 4). Since the presence of HCO_3^- in the irrigation water is related to a high pH, precipitation could occur.

Because of many ions that can be found in irrigation water, it becomes important to periodically obtain water analyses. Only by knowing what ions are present in a water can a "balanced" nutrient solution be supplied.

RECOMMENDATIONS

Factors to be considered when supplying a "balanced" nutrient solution for carnation growth using saline and/or sodic irrigation waters are:

1. Maintain $SO_4^=$ concentrations as near 1 me/1 as possible. However, carnations can produce acceptable yields at $SO_4^=$ concentrations as high as 10 me/1.

2. Maintain a K^+:Na^+ concentration ratio at 1:1 or greater. This not only reduces Na^+ absorption but also increases K^+ absorption to adequate levels.

3. Maintain Ca^{++} concentrations as near recommended levels (3 me/1) as possible.

4. Maintain Cl^- concentrations as low as possible. Two me/1 of Cl^- can be tolerated but higher concentrations may decrease growth.

5. Maintain the nutrient solution pH below 7 if possible. The presence of HCO_3^- ions indicates a relatively high pH in which nutrient precipitation can occur.

Table 8. To convert milliequivalents per liter (me/l) to parts per million (ppm) of fertilizer in solution, multiply me/l by the following constants:

Calcium (Ca)	20
Potassium (K)	39
Magnesium (Mg)	12
Sodium (Na)	23
Nitrate (NO_3)	62
Sulfate (SO_4)	48
Chlorine (Cl)	35
Phosphorous (H_2PO_4)	96
Bicarbonate (HCO_3)	61

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