COLORADO FLOWER GROWERS ASSOCIATION, INC.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
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Bulletin 254 July 1971

Nutrient Solution Concentration and Stress in the Carnation

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As salt concentration around roots increases, growth and yield of carnations decreases. Whether the decrease becomes obvious depends upon actual concentration and the environment. Nutrient levels exceeding those recommended can occur in water which initially contains dissolved salts. Most shallow wells in Colorado contain relatively high concentrations of calcium, magnesium, sodium, chloride, bicarbonate, and sulfate. Since potassium and nitrate must be supplied, usually in the irrigation system, the total concentration is increased and may result in improper nutrient ratios unless the water supply is analyzed and additions made accordingly.

In previous bulletins (CFGA 251 and 253), it was found that adequate carnation growth can be obtained as long as total concentration is in the range of -14.7 psi or lower. This corresponds to an electrical conductivity of about 3.0 millimhos. In the range of 1.0 to 3.0 millimhos (about -4.4 to -14.7 psi), ratios of different ions in solution may have a greater relative effect than actual concentration, particularly in inert media. However, to say that a carnation does not respond to changes in total solution concentration in this low range would be wrong. There are several subtle effects on various plant processes that may have considerable future importance. In soil, the effects may not be observable, except for perhaps a slight decreased yield over a long period.

Essentially, salts in solution about plant roots tend to restrict water uptake. The restriction increases internal, negative pressure inside the carnation or causes an increase in stress. The result is slower growth, or "hardening." Many species apparently have the ability to adjust to increasing salinity by increasing the concentration of ions in their individual cells. At first glance, for any given water loss rate, this would seem an excellent way to maintain equal growth over a wider range of solution concentrations. But, observations have shown a decrease in growth even with adjustment that maintains an equal or greater difference between the root solution and the inside of the carnation. The objectives of this research were to

1. determine what effects slight increases in solution concentration have on total water relations within the carnation plant.
2. offer a possible explanation as to why carnation growth decreases with higher nutrient concentrations.

Materials and Methods

White Sim carnation cuttings were rooted and planted in gravel, three per 8-inch pot, on March 27, 1970. After pinching to six leaf pairs, the plants were allowed to develop until breaks were large enough for measurement. Nutrient solutions were applied four times daily. The objective was to maintain a maximum water supply to the root system, commensurate with maximum oxygen supply. Three solutions of different concentrations were used (Table 1). Solutions 2 and 3 were four times that of Solution 1. However, Solution 2 was "balanced" (all ions in 1 increased four times), while 3 was "imbalanced" (1 doubled and Na_2SO_4 added for the remainder).

Beginning prior to sunrise, the internal negative pressure (stress) in the shoot of the carnation was determined at intervals up through the noon hour. Clear days were selected. The resistance of the stomatal pores to water loss, plant and air temperatures, relative humidity, and solar radiation and size of the stomatal pores were measured.

[1]This is a part of the work completed by Kurt A. Schekel in fulfilling the requirements for the Ph.D. degree at Colorado State University. Dr. Schekel's present address is Department of Horticulture, Washington State University, Pullman, Washington.

Table 1. Nutrient concentrations for solutions in the carnation-water relation study.[a]

Nutrient	1		2		3	
	Solution concentration					
	me/1	ppm	me/1	ppm	me/1	ppm
Ca	3.00	60	12	241	6.0	121
K	3.00	117	12	470	6.0	235
Mg	0.50	6	2	24	1.0	12
Na	0.25	6	1	23	12.5	288
NO_3	6.00	372	24	1488	12.0	744
SO_4	0.50	24	2	96	13.0	624
H_2PO_4	0.25	24	1	97	0.5	48
Total	13.50	609	54	2439	51.0	2072
Calculated Osmotic Potential (psi)	4.1		16.2		14.4	
Measured Osmotic Potential (psi)	4.4		14.7		14.7	

[a]Four ppm Fe as FeEDTA, 1 ppm B as H_3BO_4, and 0.1 ppm Zn as $ZnSO_4$ were added to all solutions.

Immediately after pressure determination, the same stem was frozen, and thawed and the sap extracted so the cell sap concentration could be evaluated.

Results and Discussion

There were no differences in stomatal opening or resistance to water movement through the stomatal pores. It may be assumed that all treatments were losing about the same amount of water. Measurements of the internal sap concentration showed that carnations over the limited range of concentrations examined here will adjust to maintain a pressure gradient between solution and the inside of the plant. In fact, this gradient showed a slight tendency to increase as solution concentration increased. Figure 1 shows results for Solution 1 and for Solutions 2 and 3 combined. Throughout the measuring period, internal concentration tended to increase, which may have been due to the root medium drying out. Concentrations are given in terms of pressure. When the mean internal concentration was -177.9 psi for -4.4 treatments, the gradient between the solution and plant was -173.5 psi. For the -14.7 psi treatments, the average internal concentration increased to 201.4 psi, with a gradient of 186.7 psi.

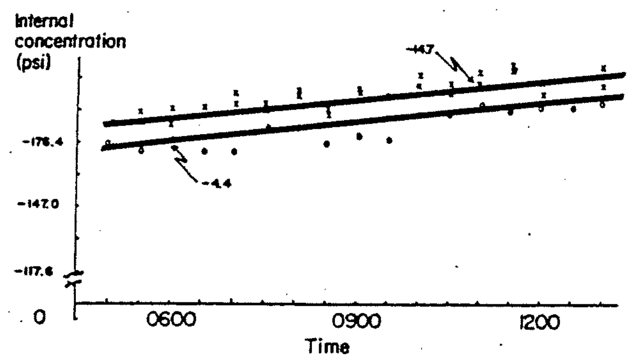

Figure 1. Effect of different solution concentrations on internal sap concentration of carnations. Concentrations are converted to pressures, psi. The -14.7 psi treatment (Solution 1) roughly corresponds to an electrical conductivity reading of 3.0 millimhos/cm; the reading for the -4.4 psi treatments (Solutions 2 and 3 combined) is about 1.0 millimho. Note the gradual increase of internal concentration during the measurement period, which was probably due to the root medium drying out.

However, when the internal stress of the carnations was plotted as a function of the environmental demand for water, it was found that increasing the solution concentration caused a higher stress (Figure 2). At low rates of water loss (environmental demand below 0.6 oz), differences were slight. As demand increased, the difference in stress between -14.7 and -4.4 psi treatments increased to approximately 44.1 psi; this difference was maintained

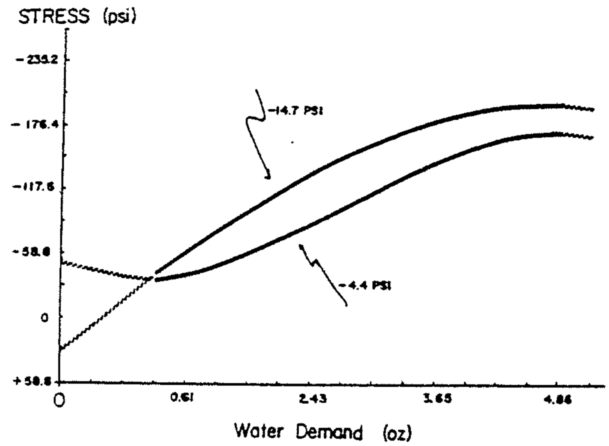

Figure 2. Effect of total nutrient solution concentration on stress in the carnation. "Water demand" is the difference in water vapor pressure within the leaf and the vapor pressure outside the leaf. The steeper the gradient, the greater the rate of water loss

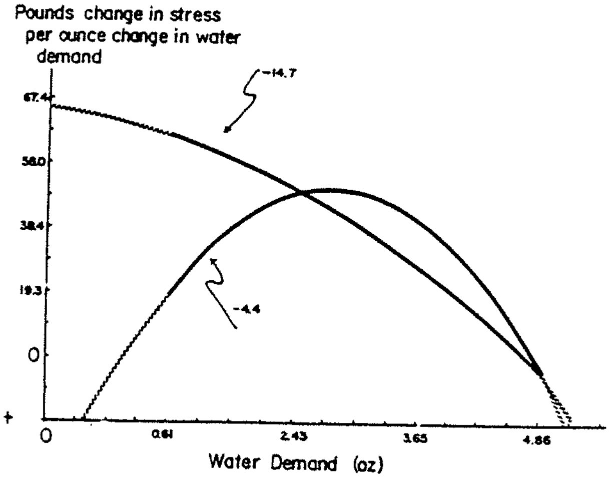

Figure 3. Effect of "water demand" upon the rate of change in stress within the carnation per ounce change in "water demand." The value 0.61 represents conditions of high humidity and low light during the early morning hours. Demand increases as light intensity increases and relative humidity decreases.

consistently up through the period when the measurements were terminated. On the basis of other information in the literature, a -4.4 psi difference is sufficient to significantly affect elongation and photosynthesis. That it does not occurr all the time is due to the rate of water loss. If water loss is high enough to cause a diffence, the amount of growth reduction will depend upon how long such differences persist. Thus, response will vary from negligible to visible depending upon 1) actual concentration, 2) time of year and, 3) water availability. One cannot say that changes in solution concentration over the range between -4.4 and -14.7 psi have no effect.

A more subtle effect of solution concentration is observable if the curves in Figure 2 are examined as to the rate of change of stress with change in environmental demand. At low demand for water loss, a slight increase in demand resulted in a large change in stress in plants grown in high solution concentrations (Figure 3). As demand continued to increase, the rate gradually approached zero. But, at low solution concentrations, a change in demand for water loss under low demand conditions caused only a slight change in pressure. As the call for water became more intense, the change in stress increased to a maximum and then began to decrease. These results point up the fact that carnation response to changes in environment and solution concentration is not straightforward until extemes are approached. The subtlety of these changes is what makes liars of all of us.

Essentially, increasing solution concentrations more than absolutely necessary is undesirable, particularly during high light periods. Use of a water supply with minimum salts is an added safety factor in carnation production, inasmuch as high demands for water are less likely to significantly affect stress, hence growth, in the carnation.

Note of Explanation

Those of us who are not too old may remember the explanation of osmosis in our high school biology classes. If two solutions of differing concentrations are separated by a membrane that permits water molecules to move freely but not the salt molecules, there will be a tendency for the water molecules to move across the membrane to the solution where the salt molecules are in higher concentration. If there is no restriction as to volume, water will continue to move until the concentrations on both sides of the membrane are equal. But, if the volume is restricted as it is in a cell, the movement of water will cause an increase in pressure until that pressure is high enough to prevent further water movement regardless of differences in concentration. The relationships between concentration, pressure, and volume are known laws of physics. We may express concentration as meq/1, ppm, or units of pressure such as atmospheres (atm), bars or pounds per square inch (psi). As we can measure cell sap concentration by determining how much the freezing point is lowered, we can convert this to pressure. Since we know pressure outside the cell from pressure bomb measurements, by subtraction or addition we can express the tendency for water to move into or out of the cell, hence the stress to which the plant is exposed. For example, in Figure 1, the cell sap concentration at 0700 was equivalent to about 162 psi. That means that a suction of 162 psi would have to be applied outside the cell to prevent water from moving in, or the maximum pressure within the cell could be 162 psi exerted on the cell walls at full turgor. If the pressure outside the cell at the same time was 117.6 psi, then the difference is 44.1 psi, which is the net tendency for water to move into the cell. If the difference is zero or negative, the cell walls collapse and the carnation wilts.