COLORADO GREENHOUSE GROWERS ASSOCIATION, INC.

Research Bulletin

Bulletin 384
Edited by David E. Hartley
June 1982

SALINITY III: HANDLING WATER SUPPLIES TO MINIMIZE SALINITY PROBLEMS

Joe J. Hanan

Precision nutrition cannot be achieved in greenhouse culture without knowledge of what is in the water supply — especially if automatic fertilizer injection is a practice. We know:

1. Bicarbonate (HCO_3^-) will be found in varying concentrations in almost any water supply in Colorado. Bicarbonate contributes nothing to plant nutrition, can be toxic, interferes with uptake of other required chemicals, and tends to increase soil pH unless counteracted.
2. Depending upon the source of the water, supplies in Colorado will contain varying amounts of calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^+), sulfate (SO_4^{-2}) and chlorine (Cl^-). Four of these elements are essential macronutrients for plant growth, and although chlorine is essential, it is considered a micronutrient, and a specific case of chlorine deficiency has never been reported. However Cl^- concentration can be high enough to be toxic.
3. Shallow wells in Colorado will almost invariably contain traces of potassium (K^+) and nitrate (NO_3^-) which are essential macronutrients, and enter the water supply by leaching from the upper soil layers in fields.

These ions that may be in water supplies, at varying concentrations, must be considered in any nutritional program if serious problems in nutrition and salt damage are to be avoided. If automatic injection is used, the grower compromises between supplying minimum nutrition without inadvertently salinizing his soils or upsetting nutritional supply to plants. Here are two general rules, regardless of water supply, and whether fertilizer injection is used:

1. Total salinity (usually measured electrically) should be as low as possible.
2. Bicarbonate should be reduced to 1 milliequivalent per liter (meq/l) or less through acidification.

Based upon some 25 years of nutritional work at CSU (White, Green, Hartman, Sadisiviah, Schekel and Hughes), a complete solution in water supplies containing less than 100 micromhos per centimeter (μmhos/cm) total salts would be:

Magnesium (Mg^{+2})	1 meq/l (milliequivalents per liter)
Calcium (Ca^{+2})	6 meq/l
Potassium (K^+)	6 meq/l
Ammonium (NH_4^+)	1 meq/l
Nitrate (NO_3^-)	12 meq/l
Phosphate ($H_2PO_4^-$)	1 meq/l
Sulfate (SO_4^{-2})	1 meq/l

This solution, in deionized water, has a pH of 5.7 with a total salinity of 1790 μmhos/cm. It was originally devised for carnations, and with varying trace element additions such as boron, zinc and iron, has been used for more than 15 years at CSU on plants produced in inert media or soils. The optimum devised for roses is slightly less. Fort Collins water, which has been utilized in most of the research at CSU, has a total salinity in the last water analysis (May, 1982) of 108 μmhos/cm, pH of 6.9, with one meq/l each of calcium and bicarbonate. It is the best water supply that we have seen in Colorado, and is one of the reasons why we have sometimes been able to obtain higher yields than commonly observed in commercial practice. The above solution represents an ideal in terms of necessary and minimum nutrition, but its use, indiscriminately, without regard to what is already present, can cause problems.

In April of this year, we obtained 6 water samples for manipulation to see what the total salt levels would be when minimum nutrients were added and acidified with eithe rsulfuric acid (H_2SO_4) nitric acid (HNO_3) or phosphoric acid (H_3SO_4). Initial water analyses of these samples are given in Table 1.

Water sample 1 was from a deep well, probably Fox Hill sands, and, with 10 meq/l sodium, would cause great difficulties in calcium nutrition and soil structure. Sample 3 was the Denver water supply, while samples 2, 4, 5 and 6 were shallow wells, number 2 from near Golden, 4 from the Clear Creek Valley in Arvada and number 6 from the Platte River Valley near Brighton. Note that, in nearly all cases, magnesium and sulfate were in sufficient supply to meet plant requirements. In two cases, significant amounts of

Table 1: Initial water analysis.

	Water sample number							
	1	2	3	4	5	6	Basic Solution	Fort Collins
Positively charged ions (cations)								
Calcium (Ca^{+2})		4	1	4	3	6	6	1
Magnesium (Mg^{+2})		2	1	2	2	2	1	Trace
Sodium (Na^{+})	10	1	1	4	3	6	0	
Potassium (K^{+})					1		6	
Ammonium (NH_4^{+})							1	
Negatively charged ions (anions)								
Nitrate (NO_3^{-})				1		2	12	
Sulfate (SO_4^{-2})	2	2	1	3	3	4	1	Trace
Bicarbonate (HCO_3^{-})	8	3	1	5	4	4	0	1
Chlorine (Cl^{-})	1	2	1	1	3	5	0	Trace
Phosphate ($H_2PO_4^{-}$)							1	
Total milliequivalents per liter	21	15	6	20	19	29	28	2
pH	8	7.4	7.7	7.8	8.2	7.9	5.7	6.9
Total salinity (μmhos/cm)	900	700	200	1000	800	1300	1790	108

nitrate were found. In one case, there was sufficient calcium (No. 6), but the high pH, bicarbonate and sodium would combine to render calcium unavailable to plants without considerable manipulation. A value of 5 meq/l chlorine is sufficient to be toxic. All samples were alkaline, and pH of soils will tend to rise unless other provisions are made to acidify the water.

A word of caution in interpreting water analyses. Determination of cations is much more accurate than analysis for anions, particularly sulfate. All-over accuracy of an analysis is usually ± 10%, and the values in the above table were rounded to the nearest whole number. The total cations should equal the total anions in meq/l, but rounding error and inaccuracy may combine to produce a one to two meq/l difference, usually in the direction of more anions (negatively charged ions) than cations. Comparison of cations versus anions is a very good check for major analytical errors. Differences should not be greater than 1 to 2 meq/l.

Theoretically, if one wishes to reduce bicarbonate and carbonate ions to zero in the irrigation supply, the same number of millequivalents per liter (meq/l) acid as the bicarbonate concentration, added to the water supply, is all that is required. In practice, other elements in solution will tend to "buffer" the water to varying degrees. In this case, the meq/l concentration of bicarbonate is a good starting point, and the final adjustment made by pH measurement. If the pH is reduced to 5.5, bicarbonate concentration in the irrigation water should be 1 meq/l or less (Fig. 1).

Fig. 2 shows the range of total salinity in these water samples as a function of total meq/l when the water samples were modified for fertilizer injection. In all cases, a minimum of 6 meq/l each K^{+} and NO_3^{-} (from potassium nitrate, KNO_3) was added. The grower has the option of adding calcium (lime) and phosphate (superphosphate) as dry applications. However, all water supplies in this test had 1 meq/l $H_2PO_4^{-}$ added. All samples had at least 2 meq/l NH_4^{+} added. When it appeared that an attempt to achieve 12 meq/l NO_3^{-} would result in high salinity, ammonium was increased. Based upon previous CSU work, waters containing high ionic concentrations generally do better if NH_4^{+} is increased, probably as a means of assuring calcium availability.

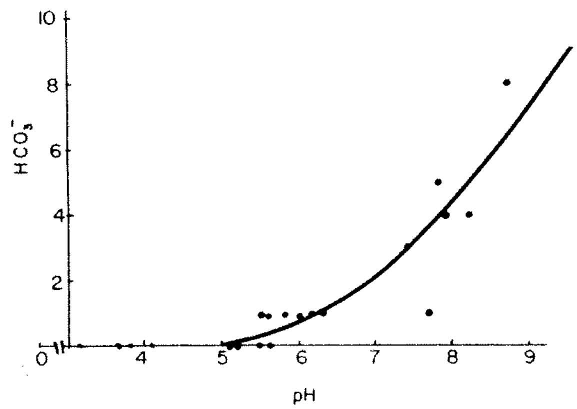

Fig. 1: Relationship between pH and bicarbonate (HCO_3^{-}) concentration in 6 greenhouse water samples modified by acidification with sulfuric, nitric or phosphoric acids. The curve, in general, follows the classic relationship between pH and HCO_3^{-} concentration published in numerous texts.

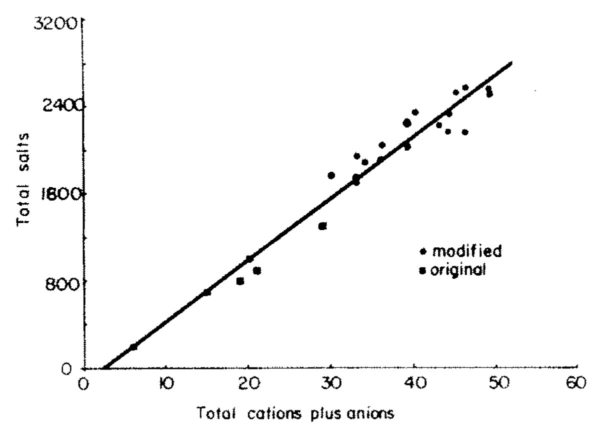

Fig. 2: Relationship between total milliequivalents per liter (meq/l) and total salinity (μmhos/cm) in 6 greenhouse water supplies acidified with sulfuric, nitric or phosphoric acid, with an attempt to supply minimum required nutrition. This curve is similar to one published several years ago by the USDA Salinity Laboratory.

Only in the case of water samples 2, 3 (Denver) and Fort Collins were we able to maintain total salinity below 2000 μ mhos/cm (Table 2).

When the same thing was attempted with water samples 1, 4, 5 and 6, total salinity was always 2000 μ mhos/cm or higher (Table 3). Sample 6 invariably exceeded 2500 μ mhos/cm, which is above the value of 2250 μ mhos/cm which the U.S. Salinity Laboratory considers as a *very high salinity hazard.* Acidity was sometimes lower than desired, but none of these should be sufficient to cause serious problems in piping systems. It is very easy to overshoot, depending upon the water quality.

Any of the three acids are suitable for eliminating bicarbonate. But, the use of sulfuric acid (H_2SO_4) or phosphoric acid (H_3PO_4) penalizes the grower since sulfate and phosphate will be in excess in the fertilizer solution in almost any water supply in Colorado — with exception of Fort Collins or Denver water. If nitric acid (HNO_3) is used, then two birds can be killed: bicarbonate eliminated and nitrate requirements partially satisfied. There is less likelihood of excessive salinity hazard. In sample 1, no calcium or magnesium was added since this would have increased total salts to near 3000 μ mhos/cm. Use of sample 6 has had a previous history of excessive salinity in greenhouse crops. The use of a potassium source such as potassium chloride (muriate of potash, KCl), even in Denver water (Sample 3), will raise total salinity above 2000 μmhos/cm, does not contribute to the nitrate supply, and does not acidify to eliminate bicarbonate. While KCl is a relatively cheap source of potassium, the ultimate costs in reduced yields are likely to be far higher. We have a suspicion that ammonium nitrate may also have a tendency to increase salinity more than other chemicals. We know the ratio of ammonium to nitrate is probably more critical than some people think, particularly in salty water supplies.

On the basis of this work and previous experience and observation, the recommendations regarding Colorado water supplies are:

1. Total salinity in the original water supply should not exceed 700 μ mhos/cm if a complete solution for automatic injection is to be used based upon CSU recommendations.
2. Total salinity *after* injection should not exceed 2000 μ mhos/cm.
3. When bicarbonate exceeds 1 meq/l, acidify the water supply to a pH of around 5.5 to 6.0 with an acid that contributes minimum salinity and still provides essential nutrition.

There are many growers who will find it difficult to meet the above requirements and still use automatic injection. There are alternatives such as changing the water supply, diluting the water with good water to achieve the required

Table 2: Analysis after injection, total salinity less than 2000 mhos/cm.

	H_2SO_4		HNO_3		H_3PO_4		
Sample No. —	2	3	2	3	2	3	Basic
Cations							
Calcium (Ca^{+2})	5	6	6	6	5	6	6
Magnesium (Mg^{+2})	2	1	2	1	2	1	1
Sodium (Na^+)	1	1	1	1	1	1	0
Potassium (K^+)	5	6	6	6	5	6	6
Ammonium (NH_4^+)	3	2	3	2	3	2	1
Anions							
Nitrate (NO_3^-)	10	12	13	13	11	13	12
Sulfate (SO_4^{-2})	6	2	3	2	3	2	1
Bicarbonate (HCO_3^-)	0	1	0	0	0	0	0
Phosphate ($H_2PO_4^-$)	1	1	1	1	3	2	1
Total milliequivalents per liter	33	32	35	32	33	33	28
pH	3.7	6.3	4.1	5.6	5.1	3.1	5.7
Total salinity (μ mhos/cm)	1900	1770	1930	1780	1710	1950	1790

Table 3: Analysis after injection, total salinity in excess of 2000 mhos/cm.

	H_2SO_4				HNO_3				H_3PO_4				
	1	4	5	6	1	4	5	6	1	4	5	6	Basic
Cations													
Calcium (Ca^{+2})	0	3	5	6	0	4	6	6	0	4	6	6	6
Magnesium (Mg^{+2})	0	2	2	2	0	2	2	2	0	2	2	2	1
Sodium (Na^+)	10	4	3	6	10	4	4	6	10	4	4	6	0
Potassium (K^+)	6	6	6	6	6	6	6	6	6	6	6	6	6
Ammonium (NH_4^+)	6	4	3	4	2	2	2	3	5	4	3	4	1
Anions													
Nitrate (NO_3^-)	11	10	10	10	11	11	11	11	11	11	10	10	12
Sulfate (SO_4^{-2})	12	9	7	10	5	6	5	7	3	6	6	8	1
Bicarbonate (HCO_3^-)	0	0	0	1	1	1	0	0	0	1	1	1	0
Phosphate ($H_2PO_4^-$)	1	1	1	1	2	3	1	1	8	5	4	4	1
Total meq/l	46	40	39	49	36	39	39	45	43	46	44	49	28
pH	3.7	3.2	5.5	6.0	5.5	5.6	4.1	5.2	4.9	5.8	5.8	5.8	5.7
Total salinity (μ mhos/cm)	2580	2360	2250	2580	2060	2040	2220	2540	2250	2170	2160	2520	1790

range, or using water purification methods. There is no good data on the trade-off between water quality, cost of improvement and increased return for greenhouses in general, except some 19 years of observation and experimentation on effects of salinity. We suggest that a total salinity above 2000 μmhos/cm will result in a 25% yield reduction on carnations and roses. In the present economy, we suggest that a grower whose irrigation water exceeds the above limits is at an economic disadvantage.

Another word of caution. Concentrated acids, particularly sulfuric and nitric are dangerous if handled carelessly. The proper clothing protection should always be worn, and when adding acid via automatic proportioning, it is safer to undershoot than overshoot. Once bicarbonate is eliminated, most of the buffering action is lost, and very acidic water, capable of causing corrosion in metal piping systems, can cause problems. Secondly, some proportioner manufacturers do not recommend using acids with their equipment, unless the machine is specifically equipped to handle such solutions. In the concentrate barrel, before injection, acid concentration will be very high, and may damage the proportioner if it is not specifically provisioned to handle corrosive solutions. Always add acid to water, *never* water to acid as boiling may spatter on people.

Published by
Colorado Greenhouse Growers Association, Inc.
Dick Kingman, Executive Vice President
2785 N. Speer Blvd., Suite 230
Denver, Colorado 80211

Bulletin 384

Direct inquiries to:
Office of the Editor
Horticulture Department
Colorado State University
Fort Collins, Colorado 80523