SOME FIGURING ON NUTRIENT SOLUTIONS FOR INJECTION

Materials available for fertilizer injection in irrigation water require, obviously, that chemicals be fully soluble in a concentrate tank. Some of the more common are:

Chemical name	Formula	Supplies these ions	Equivalent weight
Ammonium nitrate	NH_4NO_4	NH_4^+ and NO_3^-	80
Monoammonium phosphate	$NH_4H_2PO_4$	NH_4^+ and $H_2PO_4^-$	115
Diammonium phosphate (11-37-0)	$(NH_4)_2HPO_4$	NH_4^+ and $H_2PO_4^-$	66
Ammonium sulfate	$(NH_4)_2SO_4$	NH_4^+ and SO_4^{-2}	66
Calcium nitrate	$Ca(NO_3)_2 \cdot 4H_2O$	Ca^{+2} and NO_3^-	118
Sodium nitrate	$NaNO_3$	Na^+ and NO_3^-	85
Phosphoric acid	H_3PO_4	H^+ and $H_2PO_4^-$	98 (Usually 70 or 85%)
Potassium chloride (muriate of potash)	KCl	K^+ and Cl^-	75
Potassium nitrate (saltpeter)	KNO_3	K^+ and NO_3^-	101
Potassium sulfate	K_2SO_4	K^+ and SO_4^{-2}	87
Magnesium sulfate (epsom salts)	$MgSO_4 \cdot 7H_2O$	Mg^{+2} and SO_4^{-2}	123
Sulfuric acid	$H_2SO_4 \cdot H_2O$	H^+ and SO_4^{-2}	58 (Usually 85 to 90%)
Nitric acid	HNO_3	H^+ and NO_3^-	65 (Usually 85 to 90%)

If the grower wishes to supply 6 milliequivalents per liter (meq/l) nitrate (NO_3^-) in the irrigation supply then a source of nitrate can be potassium nitrate, ammonium nitrate or calcium nitrate, etc. Multiply the number of meq/l desired by the "equivalent weight" of the chemical:

Potassium nitrate: $6 \times 101 = 606$ milligrams KNO_3 per liter,
Ammonium nitrate: $6 \times 80 = 480$ milligrams NH_4NO_3 per liter, or
Calcium nitrate: $6 \times 118 = 708$ milligrams $Ca(NO_3)_2$ per liter.

Of course, these materials also supply 6 meq/l of potassium (K^+), ammonium (NH_4^+) or calcium (Ca^{+2}). This is the amount of material required for the final dilution.

If a 1:200 injector is being used, then 200 times the previously calculated amounts will give the quantity necessary per liter in the concentrate tank:

Potassium nitrate: $200 \times 606 = 121{,}200$ mg or 121.2 grams per liter,
Ammonium nitrate: $200 \times 480 = 96{,}000$ mg or 96 grams per liter, or
Calcium nitrate: $200 \times 708 = 141{,}600$ mg or 141.6 grams per liter.

If the concentrate barrel holds 100 liters, multiply by 100, or move the decimal point two places to the right:

Potassium nitrate: 12,120 g or 12.1 kilograms per barrel (100 liters),
Ammonium nitrate: 9,600 g or 9.6 kilograms per barrel, or
Calcium nitrate: 141,600 g or 14.2 kilograms per barrel.

The problem with this is the units. Conversion to English requires the factor of 3.8 liters per gallon and 453.6 grams per pound. Conversion should be the last step in the calculation:

Potassium nitrate: 12.1/0.5 kilograms per pound = 24.2 pounds,
Ammonium nitrate: 9.6/0.5 = 19.2 pounds, or
Calcium nitrate: 14.2/0.5 = 28.4 pounds per barrel.

Also, 100/3.8 = 26 gallons capacity of a 100 liter concentrate tank. There are 1000 grams in one kilogram (Kg), and 1000 milligrams in one gram. With a little practice, one can go from milligrams to grams or kilograms simply by moving the decimal point 3 or 6 places to the right or the left. It is rather more difficult with ounces and pounds.

Another difficulty is the fact that any salt completely dissolved in water provides two ionic species, positive and negative. To make a complete injection solution in good water (nothing else but water), a small table helps.

Chemical used as a source	Ionic species required								Milligrams required per liter
	H^+	Ca^{+2}	Mg^{+2}	K^+	NH_4^+	NO_3^-	SO_4^-	$H_2PO_4^-$	
Potassium Nitrate				6		6			606
Calcium Nitrate		3				3			354
Magnesium Sulfate			2				2		246
Ammonium Nitrate					1.4	1.4			119
Diammonium phosphate (11-37-0)					1.1			1.1	73
Total		3	2	6	2.5	10.4	2	1.1	
Total cations-anions			*13.5*				*13.5*		

To follow through with previous calculations (100 liter barrel, 1:200 dilution):

Potassium nitrate: $((6 \times 101 \times 200 \times 100)/1{,}000{,}000)/0.5 = 24.2$ pounds
Calcium nitrate: $((3 \times 118 \times 200 \times 100)/1{,}000{,}000)/0.5 = 14.2$ pounds
Magnesium sulfate: $((2 \times 123 \times 200 \times 100)/1{,}000{,}000)/0.5 = 9.8$ pounds
Ammonium nitrate: $((1.4 \times 85 \times 200 \times 100)/1{,}000{,}000)/0.5 = 4.8$ pounds
11-37-0: $((1.1 \times 66 \times 200 \times 100)/1{,}000{,}000)/0.5 = 2.9$ pounds

This is the Hartman-Holley formulation for good water given in Bulletin 221. The above statements, if entered into the average hand calculator as shown will provide the answers given.

However, water supplies seldom have nothing but water in them. A table is very necessary. From Bulletin 222, for a 1964 analysis of Denver, South Plate supply with a total salt conductivity reading above 300 μmhos/cm:

Chemical source to be used	Ionic species (meq/l)											Milligrams per liter
	H^+	Ca^{+2}	Mg^{+2}	K^+	NH_4^+	Na^+	NO_3^-	SO_4^{-2}	$H_2PO_4^-$	Cl^-	HCO_3^-	
Denver supply:		2.4	1.2			1.7		1.9		1.5	2.0	
Total cations-anions			*5.3*						*5.4*			
Potassium nitrate				6			6					606
Calcium nitrate		0.6					0.6					71
Magnesium sulfate			0.8					0.8				98
Ammonium nitrate					2.5		2.5					213
Phosphoric acid	1								1			98 (pure)
Nitric acid	1						1					63 (pure)
Totals	2	3.0	2.0	6	2.5	1.7	10.1	2.7	1	1.5	2.0	
Total cations-anions			*17.2*						*17.3*			

This feeding solution approximates the Hartman-Holley feeding solution. The 2 meq/l of the hydrogen ion will neutralize the 2 meq/l bicarbonate so the total meq/l of the irrigation water after injection will be 30.5 instead of 34.5 as given in this table. The acids obtained are never 100 percent pure, and they are liquid. For example, if the phosphoric acid is 70% then:

$(1/0.7) \times 98 = 140$ mg per liter H_3PO_3 required (70% H_3PO_4 actual). To convert to a liquid measure, the specific gravity or density should be known. Assume a value of 1.8. Then, 140/1800 = .08 milliliters of 70% H_3PO_4 required per liter, and the amount in 100 liters of concentrate with a 1:200 injector will be:

((.08 × 200 × 100)/1000)/.9 = 1.8 quarts liquid in a 100 liter barrel. There are 1000 milliliters in one liter, and one liter is equivalent to 0.9 quarts.

For nitric acid, 70% pure, the calculation is:

((((1/0.7 × 63)/1500) × 200 × 100)/1000)/0.9 = 1.3 quarts HNO_3 per barrel.

As another example of what happens with saltier water, a choice is again made from Bulletin 222 of a water with a total salinity of 1200 μmhos/cm. There was a discrepancy in the analysis. The total cations did not equal the total anions because no bicarbonate was given (3.5 meq/l difference), and adjustment has been made here to make them equal:

Chemical source	Ionic species (meq/l)											Milligrams per liter
	H^+	Ca^{+2}	Mg^{+2}	K^+	NH_4^+	Na^+	NO_3^-	SO_4^{-2}	$H_2PO_4^-$	Cl^-	HCO_3^-	
Shallow well		6.8	2.4			4.1	1.7	5.0		3.1	3.5	
Total cations-anions			*13.3*						*13.3*			
Potassium nitrate				6.0			6.0					606
Ammonium nitrate					2.5		2.5					213
Phosphoric acid	1.0								1.0			98 (pure)
Nitric acid	2.5						2.5					158 (pure)
Totals	3.5	6.8	2.4	6.0	2.5	4.1	12.7	5.0	1.0	3.1	3.5	
Total cations-anions			*25.3*						*25.3*			

Again, the hydrogen ions will neutralize the bicarbonate (HCO_3^-) so the total ions in solution should be 43.6, not 50.6. Total salinity is more than doubled in order to achieve a reasonable nutrient solution. Regardless of what the grower may do — unless the water is desalinized — calcium concentration is double the recommended, magnesium is slightly in excess, and sulfate is more than double the recommended. Chlorine and sodium do nothing except add to total salinity.

A total salt level of 1200 μmhos/cm in the water supply is not unusual in Colorado. It severely limits what the grower can do in maximizing yield. It reduces the effectiveness of such things as CO_2 injection, improvement in soils, photoperiodic control and precision timing. Other things to keep in mind are to separate calcium nitrate and phosphoric acid. It is best to inject calcium nitrate separately from all other chemicals. Note also that some fertilizers (calcium nitrate) come with a pelleting material which will settle to the barrel's bottom. Some sources of potassium chloride have been rather dirty. It may be difficult to distinguish between precipitate and just plain sludge. Acid to neutralize bicarbonate will reduce precipitation in the concentrate barrel and in trickle systems especially.

Nothing has been said about minor trace elements such as iron, boron, zinc, etc. Where the pH tends to be high (such as the arid Southwest), Fe_{138}, although very expensive, is more likely to prove satisfactory. Boron is a necessity in Colorado waters, and zinc may be a good idea in greenhouses where all the piping is plastic. Trace elements should be dissolved separately in hot water before adding to the concentrate barrel. Never throw borax or boric acid directly into the water — it will merely settle to the bottom of the barrel.

Over the years, observations have been made of growers replacing piping systems because of overeagerness on acids. Failure to adequately dissolve materials in barrels, unnoticed failure of injection machines, improper attention to fertilizer rates, with or without a water analysis, have occurred. This is a rather expensive way of doing business.

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PAID
Fort Collins, Colorado 80523
Permit Number 19

Dick Kingman, Executive Vice President
2785 N. Speer Blvd., Suite 230
Denver, Colorado 80211
Bulletin 413

Dr. Goldsberry
Hort. Dept.

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