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# SALINITY II: A PROBLEM IN TERMS

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Many people have talked about nutrition of plants, using terms such as "precision", "basic", "exact" and so-forth. The fact is, particularly when dealing with salinity, many of the words used in the industry are anything but "precise". The common concentration unit, parts per million (ppm), and the recommendations for "NPK" (nitrogen-phosphorus-potassium), have no direct relationship to basic plant nutrition. What difference does this make? In a time of good profits and sloppy growing, probably little. In a time of squeezed net return, where good water is difficult to obtain, and there is a high requirement for maximum turnaround in bench space and maximum yields; the use of proper terminology becomes evident.

The purpose here is to review Jim Green's earlier article on nutrition (CFGA Bul. 210, 1967). The ability to control salinity in soils, and to control nutrition in greenhouse plants, precisely and accurately, means some changes in *what* terms are used and *how* those terms are used. To quote from Richard Mitchell, probably one of the most outstanding English teachers in the U.S.:

> ". . . there is no other way to judge the work of a mind except through its words . . . .".

If the wrong terms are used in the wrong way, then the ability to improve (more profit) may be reduced when the crunch occurs. If an engineer says 6 times 7 is 45, nothing will probably happen until the plane crashes in downtown Chicago. Or, you overhear the surgeon asking which one of those doohickeys are the clamps as you sink into unconsciousness. Likewise, the industry can continue as at present, but the difference between profit and loss may be reduced.

## Some Basics

The major part of food supply to plants is by diffusion of chemical ions in the soil water to the root. The macronutrients, which are the biggest contributors to salinity are:

Nitrate ($NO_3^-$)
Ammonium ($NH^{+}_{4}$)
Potassium ($K^+$)
Magnesium ($Mg^{+2}$)

Phosphate ($H_2PO_4^-$, $HPO_4^{-2}$ or $PO_4^{-3}$)
Sulfate ($SO_4^{-2}$)
Calcium ($Ca^{+2}$)

In addition to these essential elements, water supplies and soils will often contain the following:

Chlorine ($Cl^-$)
Sodium ($Na^+$)

Bicarbonate ($HCO_3^-$)
Carbonate ($CO_3^{-2}$)

Other elements may be present, such as boron. However, the above ions are major factors to be considered in nutrition and salinity control. The essential trace elements, with exception of boron, seldom contribute much to salinity.

Note these things:

1. Nitrogen (N), phosphorous (P) and potassium (K) do not exist as N, P or K in nature. Nitrogen ($N_2$), which comprises 80% of the air, is unavailable to plants. Nitrogen is taken up by plants as $NO_3^-$ or $NH_4^+$. To use the term "N" is misleading, and really has no relationship to what actually occurs.
2. Essential elements are taken into the plant initially as ions having a negative or positive electrical charge.
3. The analysis on a bag of fertilizer provides the percentages of nitrogen (N), phosphorous pentoxide ($P_2O_5$) and potassium oxide ($K_2O$). The analysis usually does not provide any indication of source of nutrient such as ammonium nitrate, potassium chloride, etcetera.
4. A fertilizer analysis of 20-20-20 on a bag, therefore, means 20% nitrogen as "N" (which does not exist in nature and is not taken up in that form by plants), 20% $P_2O_5$ (which is actually 9% "P") and 20% $K_2O$ (which is actually 17% "K"). A recommendation of 200 ppm N, P and K is rather difficult to obtain, although it can be done, but not directly from a 20-20-20 or 10-10-10 fertilizer.

In summary, fertilizer recommendations should be given in terms of the actual ions that will be absorbed by plants. For example, ammonium nitrate ($NH_4NO_3$), which is highly soluble, will supply both $NO_3^-$ and $NH_4^+$. The fertilizer analysis does not usually provide this information. The optimum ratio of $NO_3^-$ to $NH_4^+$ can be extremely important, but the existing system generally ignores it.

## Sources of Basic Macronutrients

The essential elements, with possible exception of anhydrous ammonia ($NH_3$), cannot be purchased in the form that they are taken up by plants. The grower buys them as "salts". The major ones commonly applied in injection systems are:

Ammonium nitrate
  ($NH_4NO_3$)
Calcium nitrate
  [$Ca(NO_3)_2 \cdot 4H_2O$]
Phosphoric acid ($H_3PO_4$)
Nitric acid ($HNO_3$)
Magnesium sulfate
  ($MgSO_4 7H_2O$)
  (epsom salts)
Potassium nitrate
  ($KNO_3$)
Sodium nitrate ($NaNO_3$)
Urea $CO(NH_2)_2$

Sulfuric acid ($H_2SO_4$)
Diammonium phosphate
  [$(NH_4)_2HPO_4$]
Monoammonium phosphate
  ($NH_4H_2PO_4$)
Potassium chloride (KCL)
  (Muriate of potash)
Potassium sulfate ($K_2SO_4$)
Ammonium sulfate
  [$(NH_4)_2SO_4$]
Magnesium nitrate
  [$Mg(NO_3)_2 \cdot 6H_2O$]

When these are dissolved in water, the negative and positive particles (ions) "dissociate", that is, a solution of potassium nitrate consists of potassium ($K^+$) ions and nitrate ($NO_3^-$) ions.

The insoluble fertilizers such as:

Superphosphate (double
  or treble)
Limestone (dolomitic)
Hydrated lime (calcium
  hydroxide)

Calcium sulfate
  (gypsum)
Sulfur

are not really insoluble. They are not soluble enough to inject in a concentrated form through the water line, so they are applied "dry".

## Units

Now comes what everyone thinks is the hard part. Actually, one is better off to forget everything learned about "ppm", "pounds", "gallons" and so-on.

Every chemical compound listed previously can be characterized by a "formula" or "atomic" weight. These are:

| | | | |
|---|---|---|---|
| $NO_4NO_3$ | = 53.5 | $NH_4H_2PO_4$ | = 115.0 |
| $(NH_4)_2HPO_4$ | = 132.1 | $(NH_4)_2SO_4$ | = 132.2 |
| $CaSO_4 \cdot 2H_2O$ | = 172.2 | $Ca(NO_3)_2 4H_2O$ | = 236.2 |
| $NaNO_3$ | = 85.0 | $CO(NH_2)_2$ | = 60.1 |
| $H_3PO_4$ | = 98.0 | KCl | = 74.6 |
| $KNO_3$ | = 101.1 | $K_2SO_4$ | = 174.3 |
| $MgSO_4 \cdot 7H_2O$ | = 246.5 | $Mg(NO_3)_2 \cdot 6H_2O$ | = 256.4 |
| $HNO_3$ | = 63.0 | $H_2SO_4$ | = 98.1 |

If these numbers are taken as meaning "grams", then one formula weight (for example 101.1 grams of $KNO_3$) dissolved in one liter of water gives a concentration of one "mole" (one molecular weight). The importance of these numbers, required to give "one mole" concentrations, is that the number of molecules in one mole is the *same* regardless of the number of grams required to make that one mole. That is, one mole of sodium nitrate will have the same number of "particles" as one mole of magnesium sulfate, or 602,000,000,000,000,000,000,000.

Chemical reactions take place on an "equivalency" basis. That is, an "equivalent" of ammonium nitrate will react with an "equivalent" of nitric acid. Equivalency is determined by the electrical charge. Since ammonium nitrate is highly soluble, one mole of $NH_4NO_3$ will contain one mole each of $NH_4^+$ and $NO_3^-$ and one liter of one mole ammonium nitrate will contain one equivalent of ammonium and one equivalent of nitrate. One mole of calcium nitrate, however, will convert to two equivalents of calcium and two of nitrate since calcium has two positive charges ($Ca^{+2}$) and there are 2 nitrates for each calcium ion. To determine the number of equivalents in one mole of a chemical compound, multiply by the number of electrical charges on the ion.

There are 1000 milliliters in one liter. Therefore, if one has dissolved 101.1 grams of potassium nitrate in one liter of water, each milliliter will contain one one-thousandths of an equivalent each of $K^+$ and $NO_3^-$, or one "milli-equivalent". If one takes one milliliter from a jar which has one mole per liter of $KNO_3$, and puts it in another jar containing one liter of water, the final concentration of potassium ($K^+$) is one milliequivalent (1 meq), and of nitrate ($NO_3^-$) one milliequivalent (1 meq). Each milliliter of *that* water will contain 0.001 meq $K^+$ and $NO_3^-$ each.

Likewise, suppose the grower does not want to make a stock solution of ammonium sulfate [$(NH_4)_2SO_4$). If the formula weight is expressed in milligrams (mg), and this amount (132.2mg) is dissolved in one liter, the concentration will be one millimole, and there will be 2 meq per liter ($SO_4^{-2}$ has a double charge and there are two $NH_4^+$'s). To summarize the units:

One gram = 1000 milligrams (mg)
One equivalent = 1000 milliequivalents (meq)
One mole = 1000 millimoles (mm)
One liter = 1000 milliliters (ml)
One cubic meter = 1000 liters (l) = 1,000,000 cubic centimeters

Note:
1. Expressing concentrations in the above units puts everything into "fundamental" units that relate directly to each other.
2. The elements important in salinity and nutritional control are given equal time.
3. This system is less prone to mistakes and a damn sight easier once one gets over the hassle of learning new terms.

### Some Important Considerations

The utilization of this terminology comes home when considering:
1. Neutralization of bicarbonates in water supplies. The chemical reaction required to convert $HCO_3^-$ to carbon dioxide ($CO_2$), thus getting rid of a toxic substance, is directly based upon equivalency. If there are 6 meq/l $HCO_3^-$ in solution, then 6 meq/l sulfuric acid or 6 meq/l $HNO_3$ will get rid of it.
2. Adjusting pH of acid or alkaline water supplies is directly based upon equivalency.
3. One can now compare concentrations of ammonium versus nitrate versus sodium, and so on. The manipulation of water supply can be carried forward in the most efficient manner. Soil tests and water analysis reports have recently been converted to moles in Holland.

### For Those Who Need It —

Here are some conversions for those who wish to make them:

One gallon = 3.8 liters
One pound = 453.6 grams
One quart = 0.9 liters
One ounce (avoirdupois) = 28.4 grams
One cubic foot = 28.3 liters
One cubic yard = 0.8 cubic meters
One cubic inch = 16.4 cubic centimeters
One pint = 0.5 liters
One teaspoon = 5 cubic centimeters, about 5 milliliters
One bushel = 35.2 liters
One ounce (fluid) = 29.6 cubic centimeters or about 29.6 milliliters

For those who must use ppm, conversion between equivalency and ppm requires knowledge of the atomic weight of the ion. These are:

Nitrate ($NO_3^-$) = 62.0
Bicarbonate ($HCO_3^-$) = 61.0
Phosphate ($H_2PO_4^-$) = 97.0
Chlorine (Cl) = 35.5
Potassium ($K^+$) = 39.1
Ammonia ($NH_4^+$) = 18.0
Sulfate ($SO_4^{-2}$) = 96.0
Calcium ($Ca^{+2}$) = 40.1
Magnesium ($Mg^{+2}$) = 24.3
Sodium ($Na^+$) = 23.0

To convert milliequivalents to ppm, multiply the number of meq by the atomic weight, to go to the opposite, divide. If there are 2 electrical charges (for example, $Ca^{+2}$), divide the atomic weight by 2.

The next discussion on salinity will deal with the use of various acids to neutralize bicarbonate, and the effects the different acids have on total salinity in some typical Colorado water supplies. We will see that logical discussion on how to handle saline waters, and what happens, cannot be discussed intelligently without using the terminology described in this article.