WATER QUALITY AND PLANT PRODUCTION IN CONTAINERS

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When considering factors that affect plant production in containers, water quality is generally considered but only passively. In the past, as long as the water had a salt level below 500 ppm, it was considered acceptable. The other factor often measured was pH. Unfortunately, pH is frequently used to judge the quality of irrigation water. But pH is only a measure of the relative proporations of acids and bases in the water. Neither soluble salts nor pH measurements give any clue to *what* salts are actually dissolved in the water. If pH is below 7.0, it means only that there are more acid-forming materials in the water than bases, or vice versa if it is above 7.0.

To demonstrate how little information pH of water actually provides, try this: take a sample of distilled water and measure the pH. If the distillation process was working properly, pH will be 7.0; and if a chemical analysis of the water is done, it will show no dissolved salts. Now add enough acid, any acid, to another sample of distilled water to make it read pH 4.0. To still another sample of distilled water add enough base (calcium hydroxide, slaked lime, sodium hydroxide, or other base) to make the pH of the water rise to 10.0. Now add the water from both these containers to the original container of distilled water, stir well, and measure the pH. If you have been accurate in your measurements and technique, the pH of the water is still 7.0. You can continue to add equal portions of acids and bases to the original water sample and as long as you add the same quantity of acid as you do bases, the pH of the solution will remain 7.0. Does pH of the irrigation provide any useful information? No. It does not give a single clue as to the total salt level in the water, only the relative proportion between acids and bases. Only a water quality analysis will show what is actually dissolved *in* the water.

Elements *dissolved* in irrigation water may or may not have a direct effect on plant growth. It depends on whether or not they are essential for plant growth, their concentration, and proportion or ratio to other elements. Two essential elements that are plentiful in most irrigation waters are calcium and magnesium. Calcium or magnesium dissolved in irrigation waters are available for plant growth, just as potassium or nitrogen are when injected into the water (1). For example, assume irrigation water contains 43 ppm calcium and 15.5 ppm magnesium, and approximately 1 in. of irrigation water is discharged each application for 150 applications/year, then 0.0066 lbs. of calcium and 0.00238 lbs. of magnesium per 1 gal. container will be applied.

This is based on the following calculations:

A 6-in. container has a surface area of 28.3 in.^{2} ($3.1416 \times 3 \times 3$ or $\pi \times r^2$) 28 in.^{2} × 150 applications of one-inch each = 4.245 in.^{3} of water. Divide 4245 by 1728 (the number of in.^{3}/ft.^{3}) to get 2.46 ft.^{3} of water applied per container per year. If the water contains 43 ppm, there are 43 lbs. of calcium in 1,000,000 lbs. water. There are X lbs. of Ca in 153.6 lbs. of water (the weight of the 2.46 ft.^{3}/container/year. We find that X = 0.0066 lbs. of Ca per container per year from the water.

This seems like a very small amount of calcium; however, to grasp the relative amount, calculate the amount of Ca supplied per container if 9 lbs. of dolomite is added/cu. yd. of mix. If 9 lbs. of dolomite is added/yd.^{3}, it is necessary to know the volume of the container in cubic inches in order to calculate the amount of dolomite received by each container. Most "one gallon" containers hold about 160 in.^{3}. One yd.^{3} = 46,656 in.^{3}. so that we can say 9 lb./46,65614^3 = X/160 in.^{3}, we find that × = 0.03086 lbs. However dolomite is about 20% Ca. Therefore $0.03086 \times 0.20 = 0.00617$ lbs. Ca per container.

The same steps are followed to calculate the amount of magnesium supplied by the water as compared to the dolomite. However, dolomite is generally only 10% Mg. Therefore, 0.03086 lbs. × 0.10 = 0.003086 lbs of Mg/container from the dolomite.

In this case the quality of the irrigation water had a greater influence on the calcium level received by the plant than the 9 lbs. of dolomite added to the basic growth medium.

It would be easy to stop here in a general discussion of the influence of calcium and magnesium in irrigation water on plant nutrition, but a very important point would be missed.

A study of the solubilities of various calcium and magnesium sources shows a dramatic difference in solubility of sources of the two elements. The "Handbook of Chemistry and Physics" (CRC Press, Boca Raton, Fl.) lists the following solubilities for calcium and magnesium sources (Table 1).

The solubility of the calcium carbonate portion of the dolomite is only 0.0014 grams/100 ml. of water. By considering the number of irrigations required to dissolve all the calcium carbonate, *we find it will require approximately 7.15 years to* dissolve the calcium.

Now reconsider the 0.0066 lbs. (3.0 grams) of calcium supplied by the water that contained only 40 ppm calcium. The water supply is actually supplying over 7 times *more soluble* calcium to the container system during one growing season than the dolomite at the 9 lbs. yd.[3] rate.

Table 1. Solubility of sources of calcium and magnesium.

	Solubility in cold water, gm./100 milliliters of water
Calcium carbonate	0.0014
Calcium oxide	0.131
Calcium sulfate	0.209
Magnesium carbonate	0.176
Magnesium oxide	0.00062
Magnesium sulfate	26.0
Dolomite (calcium and magnesium carbonates)	0.032

Magnesium carbonate is much more soluble than calcium carbonate (0.176 in the pure state and 0.032 gm/100 ml. of cold water in dolomite). Doing similar calculations with magnesium in the water supply and in the dolomite reveals a similar effect. However, in this case, since the water contains only 15.5 ppm magnesium, and the magnesium fraction of the dolomite is much more soluble (0.032 instead of 0.0014 for calcium carbonate), most of the magnesium from the dolomite would be dissolved after about 30 waterings or about one-third through the growing season.

Actually, this is not an abrupt end to the availability of magnesium for plant growth. When magnesium and calcium are released from the dolomite, they are adsorbed onto the growth medium by the cation exchange capacity since both are strong cations with two positive charges. However, calcium is a stronger cation than magnesium since magnesium is always surrounded by water of hydration, which weakens its electrical charge. If most of the sites are already filled with calcium, the magnesium will be more readily lost to leaching since it cannot be adsorbed as strongly. Even if the magnesium has been released by the dolomite and absorbed by the growth medium, calcium released from the dolomite or added from another source will replace the magnesium.

If additional dolomite is top-dressed on plants in containers showing magnesium deficiency, the result can be confusing. Within a week or two the plants will respond to the additonal magnesium provided by the dolomite if they are otherwise healthy. However, the response will be short-lived and soon the plants will develop magnesium deficiency symptoms more severe than before. The reason is due to the rapid solubility of the magnesium contained in the dolomite. As soon as the bulk of the magnesium is released, the calcium that remains causes an even wider and less favorable ratio of calcium to magnesium than before.

If dolomite is used in the base mix and magnesium deficiency is suspected, liquid applications of magnesium sulfate, ($MgSO_4$, Epsom salts) should be applied. A rate of approximately one lb. $MgSO_4$ per 100 gal. of water provides approximately 100 ppm actual magnesium. The magnesium should be applied every 10 to 14 days, or as needed. It can also be sprayed on the foliage at a rate of 5 to 8 lb./100 gal. water every 7 to 14 days. Dispensing magnesium sulfate through an irrigation system during cool weather may not be practical since it is difficult to keep in solution at temperatures below 60°F (15°C).

It can be seen from this discussion that excess calcium can strongly interfere with magnesium nutrition in several ways.

Now go back to the example dealing with the water quality. Since, in addition to the 40 ppm calcium, the water also contains 15.5 ppm magnesium, there is about 1.0 gram of magnesium added to the one-gal. container during the growing season. Therefore, the plants are liquid fertilized with magnesium as well as calcium throughout the growing season. This magnesium in the water supply prevents plants from suffering severe magnesium deficiencies in spite of the short effectiveness of dolomite in supplying magnesium.

If the rapid solubility of magnesium from dolomite, the accumulation of calcium in the growth medium at the expense of the retention of magnesium, and the importance of a ratio of calcium to magnesium of about 2-to-1 for excellent growth are true, plant growth should improve by using only this water source plus additional magnesium during the growing season. Dolomite would not be needed in the medium.

To test this hypothesis, magnesium-deficient liners of Wilton carpet juniper (*Juniperus horizontalis* 'Wiltonii') and healthy liners of shore juniper (*Juniperus conferta* 'Blue Pacific') and dwarf yaupon holly (*Ilex vomitoria* 'Nana') were grown with 1, 3, 6, or 9 lbs. of dolomite/yd.^{3} (0, 1.8, 3.6 or 7.2 kg./m.^{3}). A second group was grown with no dolomite added to the mix, but with magnesium sulfate added to provide magnesium equivalent to what the first plants received from the dolomite. Because the magnesium sulfate is very water soluble, one-half of each rate was added at planting time and one-half was added midway during the growing season. The plants in Figures 1 and 2 show the benefit of the improved calcium:magnesium ratio and the fact that a water supply with 40 ppm calcium can supply most, if not all, of the calcium needs of the plants. Plants of all three species were larger and had many more branches with the supplemental magnesium and no calcium other than that in the water.

The magnesium deficiency symptoms (yellowing of the older leaves) that were present on all liners at time of planting

Figure 1. Magnesium-deficient liners of Wiltoni juniper grown with (from left) no added calcium or magnesium other than that supplied by the water, or 3, 6 and 9 lbs. of dolomite/yd.^{3} or the equivalent magnesium that would have been applied had 6 or 9 lbs. of dolomite been used without the calcium proportion. The 6 and 9 lb. equivalent rates of magnesium was supplied by magnesium sulfate applied ½ at planting and ½ midway during the growing season. Note the decline in plant growth with the additional dolomite from 0 to 9 lbs./yd.^{3} and the excellent growth from both rates of magnesium sulfate.

Figure 2. Blue Pacific shore juniper grown for 6 months in one-gal. containers with (from left) 0 to 6 lbs. of dolomite/yd.^{3} of mix or the equivalent magnesium that would have been applied had 6 or 9 lbs. of dolomite been used without the calcium proportion. The 6 and 9 lbs. equivalent rates of magnesium were supplied by magnesium sulfate applied ½ at planting and ½ midway during the growing season. The plant on the left (0) recieved only the calcium and magnesium supplied by the water, plus a small amount in the pine bark portion of the growth medium.

never re-developed.

The results of this experiment confirm the fact that dissolved salts in the irrigation water play a major role in nutrition of plants grown in containers. Water quality must be considered part of the overall nutritional program if maximum growth and quality are to be achieved.

LITERATURE CITED

1. Whitcomb, Carl E. 1984. Plant Production in Containers. Lacebark Publications, Stillwater, Oklahoma

BUILDING A HIGH HUMIDITY PROPAGATION SYSTEM

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We have been using high-humidity propagation at Colesville Nursery for five or six years. In 1982 I presented a paper to the IPPS - Southern Region (1), on our use of the Agritech high-humidity propagation system. While this system did work fairly well for us, the maintenance cost on the motors and other moving parts in the units became prohibitive. Also, the uniformity of the moisture was very irregular.

While visiting nurseries in Oregon in 1984, Al Gardner and I saw a small fog system at Mitch Nursery, which John Mitch was experimenting with in his operation. John, very graciously, shared all the information he had with us. Back in Virginia we began to construct a similar fog system in our 20 × 100 ft. propagation house.

A fog or high humidity system operates by atomizing water into microscopic droplets. These droplets are suspended in the air of the greenhouse creating an ideal atmosphere for plant propagation. The air is kept humid while not overly wetting the soil medium. In our case we are using high water presure to force the water through very small nozzles.

Our system starts with the water-feed line leading into a low pressure switch. The purpose of this switch is to safeguard the fog system pump in case the water pump in the well fails. From here the water goes through two water filters: the first has a wire screen filter and the second has a felt filter. The fog nozzles have an extremely small orifice; even with the two filters, a nozzle occasionally clogs up.

The water continues from the filters to a solenoid valve which, in our case, is controlled by a 5-min. time clock that, in