Alternative Sources of Secondary Macronutrients

Thomas D. Landis

Conventional fertilization is mainly concerned with the "Big Three" macronutrients - nitrogen, phosphorus, and potassium which together comprise over 75% of the mineral nutrients found in typical plant tissue. So, it's easy to forget about the importance of the "secondary macronutrients" - calcium, magnesium, and sulfur. To make matters worse, the symptoms for these mineral nutrients are not particularly diagnostic. For example, native plant seedlings do not exhibit visible calcium deficiency symptoms such as "blossom end rot" of tomatoes and peppers. In fact, I'm embarrassed to admit that these symptoms in my vegetable garden this spring brought the importance of these nutrients to my attention. After all, I'm supposed to know something about growing plants!

This experience caused me to reevaluate the options for supplying calcium, magnesium and sulfur as fertilizers and, in particular, look for new options for nurseries.

Calcium is seldom in the spotlight in conifer seedling culture because it is found in all but the most acid soils, and also is commonly present in irrigation water. The "lime" that has traditionally been added to nursery soils and incorporated into growing media to raise pH is an excellent source of calcium and magnesium so growers feel that they don't need to worry about this critical nutrient.

Calcium has several critical functions in plant metabolism and structure. Calcium pectate acts as a physical barrier to fungal hyphae penetration and high calcium levels inhibit the polygalacturonase enzyme which fungi, such as *Fusarium* and *Pythium* spp., manufacture to invade plant tissue. This means that young germinating plants should have an immediate source of calcium to ward off disease. In addition, calcium pectate is needed for strong cell walls and so calcium nutrition becomes particularly important during hardening.

Calcium deficiencies can reach severe levels before they are noticed because they occur first in the meristems which are not readily visible - buds are cloaked within other tissues and root tips are buried in the soil (Figure 1A). In the case of root tips, a problem with calcium supply results in a complete cessation of root extension within only a few hours (Figure 1B).

Although magnesium is most well-known as the only metallic constituent of the chlorophyll molecule, this macronutrient has many other physiological functions in plants. Magnesium is found naturally in many bareroot soils and is also common

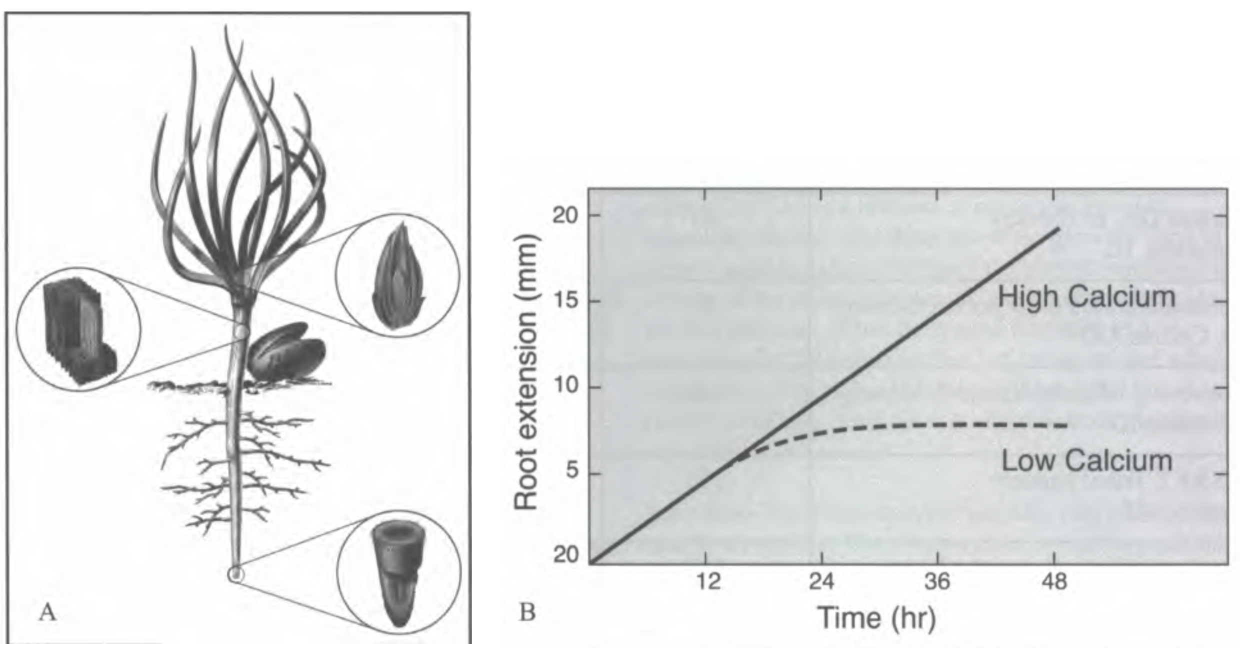

*Figure 1- In trees and other native plants, calcium deficiency affects the meristems (A) which are not visible. In the case of root tips, a problem with calcium supply results in a complete cessation of root extension within only a few hours **(B).***

in irrigation water. In the sandy soils favored for bareroot nurseries, however, heavy rainfall and frequent irrigation can leach the magnesium ions out of the root zone. Because it is a chemical constituent of vermiculite, magnesium is found at low levels in some artificial growing media. However, this is not enough to supply the needs of rapidly growing seedlings.

Foliar chlorosis is the typical symptom of magnesium deficiency, but the position, pattern and timing of the symptoms are not diagnostic in native plants. Because magnesium is mobile within plant tissue, translocation from older to younger foliage will occur, causing deficiencies to show in older tissue first. Note that visual symptoms do not develop until the magnesium deficiency is severe, by then, serious growth loss has already occurred.

Sulfur is rarely applied as a fertilizer in traditional agriculture because it is commonly found in soil minerals and is also supplied in rain and irrigation water. Because sulfur is found in both available and unavailable forms in the soil and the concentrations of these form varies over time, bareroot nurseries shoulc have their soils tested for sulfur on an annual basis to determine if fertilization is warranted. Artificial growing media components like peat moss, vermiculite and perlite contain essentially no available sulfur.

The fact that sulfate is an anion affects its availability in 2 ways: first, elemental sulfur must be oxidized before it can become absorbed, and second, sulfate anions are not strongly held in the soil or growing medium. So, unlike calcium and magnesium which can accumulate on the cation exchange sites in the soil, sulfur leaches readily form the root zone and so must be regularly supplied to a growing crop.

Ways to Supply the Secondary Macronutrients

Irrigation Water - As previously mentioned, irrigation water often contains enough calcium, magnesium, and sulfur to supply plant needs. However, their concentrations vary considerably from nursery to nursery depending on the source of the water and the local geology (Table 1). Because it has had less time to dissolve soluble minerals in the soil, irrigation water that is obtained from surface sources such as streams and ponds will usually have lower soluble salt levels than water from underground sources. The water at many places in the western US is called "hard" because it contains high levels of calcium and magnesium that cause scale to accumulate in pipes and also leaves deposits.

Nurseries with moderately hard water are fortunate because it often supplies all or most of the calcium and magnesium requirements. As you can see in Table 1,

Table 1 - Irrigation water can be a significant source of the secondary macronutrients but the amounts vary considerably from nursery to nursery

Nursery	Total Salts - Electrical Conductivity (msm/cm)	Calcium (ppm)	Magnesium (ppm)	Sulfate - Sulfur (ppm)
Hawaii Div. of Forestry Kamuela, **HI**	40	1	1	1
Colorado State Forest Service Nursery Ft. Collins, CO	58	7	1	11
University of Idaho Research Nursery Moscow, ID	240	25	10	4
CS&KT Tribal Nursery Ronan, MT	280	35	14	1
Los Lunas Plant Materials Center Los Lunas, NM	520	17	5	31
California Div. of Forestry Davis, CA	1610	66	113	315
Target Ranges	**0 to 500**	**40 to 80**	**20 to 40**	**30 to 80**

Figure 2 - Fertigation is the only way to ensure that each container receives the same amount of fertilizers (A). Bareroot nurseries are starting to apply the lessons learned from container culture and applying soluble fertilizers to their fields (B).

however, the base levels of these 2 mineral nutrients in irrigation water varies considerably. The amount of sulfur in irrigation water also varies widely: a recent survey from across the US found that 4% of the water samples contained no sulfur, and another 65% contained less than 10 ppm. Compared to a target level of around 60 ppm, this is too low to supply the needs of rapidly growing seedlings.

Traditional Sources

Dolomitic Limestone in Bareroot and Container Nurseries - This has been the best choice for supplying both calcium and magnesium in both bareroot and container nurseries. In addition, the carbonate ions raise the pH of the soil or growing medium so dolomite is applied to bareroot nursery soils prior to sowing or incorporated into growing media. This practice is effective in bareroot nurseries where plant roots have access to larger soil volumes. Small container plants, however, only have access to a very limited volume of growing medium and problems in even distribution of the dolomite can cause variable growth patterns.

Fertigation in Container Nurseries - Injecting soluble fertilizers is the only way to ensure that calcium and magnesium will be available at the proper concentration and ratio. Custom-mixed fertigation solutions should contain a target concentration of around 80 ppm calcium and 40 **ppm** magnesium with a Ca to Mg ratio between 2:1 and 3:1. Be aware that most commercial soluble and slow-release fertilizers do not contain calcium or magnesium due to problems with solubility in concentrated stock solutions.

Soluble, Readily-available Sources

Progressive nursery managers are realizing that, next to proper irrigation, custom fertilization is the most effective way of increasing the growth rate and quality of their stock. Injecting soluble fertilizers in the irrigation system ("fertigation") ensures that the same amount of soluble fertilizer is applied to each container (Figure 2A). Some progressive bareroot nurseries are starting to apply soluble fertilizers to their crops to ensure that the nutrients are readily available to small, rapidly growing seedlings early in the growing season (Figure 2B).

Compared to the other mineral nutrients, there are fewer soluble options for the secondary macronutrients (Table 2). However, calcium, magnesium, and sulfur can be supplied with only 2 fertilizers: calcium chloride ($CaC1_2$) and epsom salts ($MgSO_4$). Calcium is the most difficult mineral nutrient to supply through fertigation because only two soluble forms are available. Calcium nitrate($CaNO_3$) is a favorite of container growers especially during hardening but often growers want to supply soluble calcium without the growth stimulating effects of the added nitrogen. Calcium chloride is ideal for this purpose. **It** has been used for years as a treatment for "blossom end rot" of tomatoes and other vegetables (Figure 3). Ordinary epsom salts is a cheap, readily available fertilizer that supplies both magnesium and sulfur.

Both these fertilizers are very soluble, inexpensive, and readily available. The only caution is that they should not be tank-mixed because of solubility problems.

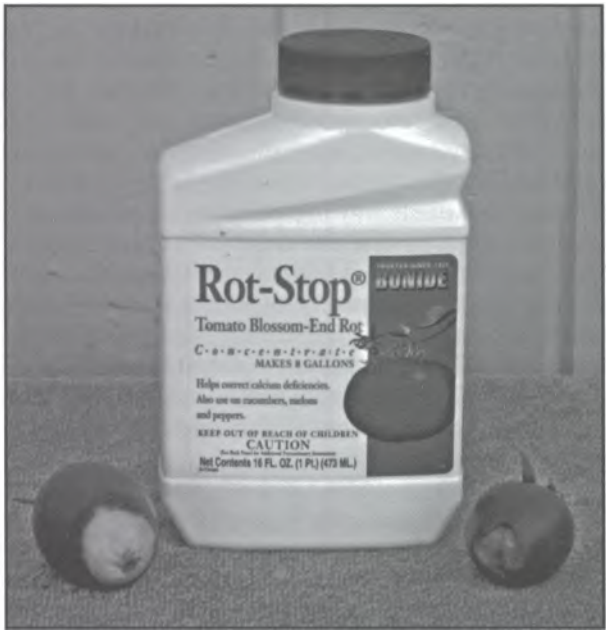

Figure 3 - Calcium chloride is widely used as a foliar treatment for the physiological disease known as "blossom end rot" of tomatoes, but this fertilizer is not commonly used in native plant nurseries.

Summary

Because they are often found in irrigation water, the secondary macronutrients are often overlooked by nursery managers. Adequate supplies of calcium, magnesium, and sulfur should be made available to young developing seedlings. In particular, a ready source of calcium is needed for new root growth and also inhibits damping-off and other root rot fungi. Fortunately, all 3 secondary macronutrients can be easily supplied to both bareroot and container crops through fertigation with calcium chloride and epsom salts.

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