Cultural Perspectives

Secondary Nutrients-Magnesium

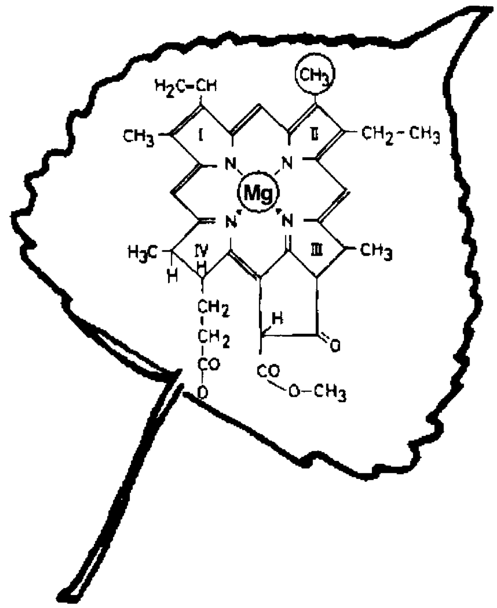
In the last FNN issue, we took a more detailed at the three "secondary" mineral nutrients, beginning with calcium. We'll continue with magnesium in this issue, and finish-up with a discussion of sulfur in the next one. Again, Eric van Steenis of the British Columbia Ministry of Forests contributed to the writing of this section.

Role in Plant Nutrition

Although magnesium concentrations are typically less than 1% of plant tissue (Table 1), this essential mineral nutrient serves some critical structural and physiological functions. Magnesium is most well-known as the only metallic constituent of the chlorophyll molecule where it occupies a critical central position, similar to that occupied by iron in blood hemoglobin (Figure 1). This structural function accounts for only about 25% of the magnesium in plant tissue, however, so this critical element also serves several other important physiological functions:

* **Cellular pH regulation and cation-anion balance.** Magnesium ions with their double charge (Mg^{2+}) are very mobile within cells, which allows them to be involved in the regulation of cellular pH and cation-anion balance. Because they are quickly transported through the phloem, magnesium ions can quickly be transported to other areas of the plant where concentrations are below optimal levels.

Figure 1. Magnesium forms the structural "heart" of the chlorophyll molecule.



***Energy transfer.** Magnesium functions in enzyme activation and the transfer of energy-rich phosphoryl groups (ATP) within cells; it helps regulate energy-requiring reactions, such as mineral nutrient uptake and the transport of photosynthates.

Table 1. The three "secondary nutrients": Calcium, Magnesium, and Sulfur

Element	Symbol	Average Concentration in Plant Tissue"%	Adequate Range in Seedling Tissue (%) Container	Bareroot
Nitrogen	N	1.5	1.20 to 2.00	1.30 to 3.50
Potassium	K	1.0	0.30 to 0.80	0.70 to 2.50
Calcium	Ca	0.5	0.20 to 0.50	0.30 to 1.00
Magnesium	**Mg**	**0.2**	**0.10 to 0.15**	**0.10 to 0.30**
Phosphorus	P	0.2	0.10 to 0.20	0.20 to 0.60
Sulfur	S	0.1	O.10to0.20	0.10to0.20

***Enzyme stabilization and "bridging".** Magnesium ions can form both ionic and covalent bonds; they function as a bridging element, making structures more stabile. Within enzymes, this bridging helps establish the precise geometry with their substrates; it also facilitates the ribosome subunits during protein synthesis.

Availability and Uptake

Magnesium is found naturally in many soils and becomes available for plant uptake as the minerals weather. The magnesium canons are held on canon exchange sites on clays or organic matter particles until they are taken up by plant roots (Figure 2-A). Deficiencies most typically occur in coarse-textured soils in humid regions, such as the coastal plain of the Southeastern United States. Magnesium availability is not a problem in most bareroot nurseries unless soil pH is allowed to drop too low. If soils become too acidic, magnesium can be leached below the effective rooting zone (Figure 2- B).

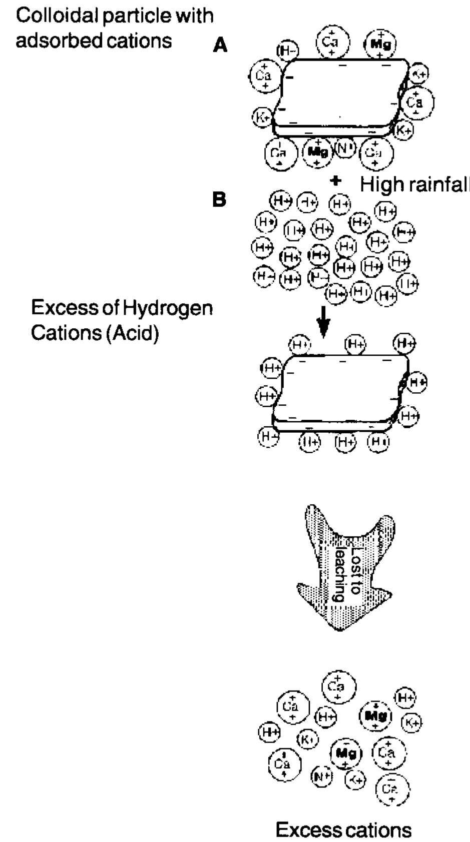


Figure 2. The ideal level of magnesium for plant growth is when it occupies about 10% of the cation exchange capacity of the soil (A). Under acidic, high rainfall conditions, however, it can be rapidly leached from the rooting zone and become deficient (B).

Because it is a chemical constituent of vermiculite, magnesium is found at low levels in many artificial growing media; however, this is not enough to supply the needs of rapidly growing seedlings. Therefore, container nurseries must supply it as dolomitic limestone or in soluble fertilizers.

Diagnosis of Deficiencies and Toxicities

Foliar chlorosis is the typical symptom of magnesium deficiency, but the position, pattern and timing of the symptoms are most diagnostic:

Conifers:

Yellow tips of young needles which can turn into tip necrosis in extreme deficiencies. In classic experiments with Sitka spruce, the chlorotic needles of the upper shoot were described as "hard yellows" because they stood out rigidly from the stem. The symptoms characteristically develop late in the growing season and typically occur in patches surrounded by normal green seedlings.

Broadleaves:

Hardwood seedlings show very characteristic interveinal chlorosis which can become necrotic.

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. Soil and tissue testing can identify a potential problem much more quickly so that corrective actions can be taken.

Magnesium toxicity has not been found to be a problem in horticultural situations, although excesses could induce deficiencies of other mineral nutrients, especially calcium and potassium.

Monitoring

Bareroot nursery managers should use annual soil tests to determine the base magnesium levels in their soils, but, in most cases, maintaining pH in the recommended 5.5 to 6.5 range is a more practical concern. Container growers who fertigate can monitor the applied fertilizer solution for both the magnesium concentration and its ratio to other nutrients. Analysis of the saturated media extract and leachate can also give a good indication of magnesium availability and seedling use. Because magnesium is a common component in irrigation water, nursery managers should have their irrigation water analyzed. Some "hard" irrigation waters contain enough magnesium to meet all nutritional requirements, but growers also have to consider the calcium : magnesium ratio. Plant tissue analysis can be useful in diagnosing magnesium deficiencies (Table 1), especially if growers have established base-nutrient levels for their own species.

Magnesium Management

* **Analyze your irrigation water.** A complete water quality analysis will indicate both magnesium and calcium concentrations, and be sure that calcium and magnesium levels are balanced.

* **Monitor soil and growing medium pH.** In bareroot nurseries, maintaining a soil pH between 5.5 and 6.5 keep magnesium available unless a specific deficiency has been identified. Dolomitic limestone ($CaCO_3$ •$MgCO_3$) is the best choice for raising pH because it contains both calcium and magnesium in the proper nutrient ratio. The nutrient release-rate is dependent on particle size, and the magnesium fraction is much more soluble than the calcium fraction. Other liming materials, such as calcic limestone ($CaCO_3$) and hydrated lime [$Ca(OH)_2$] contain no magnesium, whereas magnesia (MgO) contains no calcium (Table 2). The proper application rate of dolomite depends on initial pH, soil texture, and organic matter content; easy-to-use tables are available to calculate this rate.

* **In container nurseries, formulate well-balanced fertigation solutions.** Although some commercial growing media contain incorporated dolomitic limestone, fertigation is the only way to insure that magnesium will be available at the proper concentration and ratio. Custom-mixed fertigation solutions should contain a target concentration of around 40 ppm magnesium with a Ca:Mg ratio between 2.1 and 3:1, and a K:Mg ratio from 2.5:1 to 4:1 on a ppm basis. 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. The Peters Excel® line of fertilizers is specially formulated so that they are compatible with soluble magnesium fertilizers. Although their "All Purpose" formulation contains no magnesium, the specialty formulations "Cal-Mag" and "Magnitrate" contain from 2 to 9% Mg (Table 2). If you incorporate slow-release fertilizers in your media, check the product labels to be

Table 2. Fertilizers containing magnesium for bareroot or container seedlings

Fertilizer	Magnesium Content	Other Nutrients	Use in Nurseries
Magnesia	56%	None	A cheap source of Mg and will also raise soil pH
Mag-Amp®	15	Nitrogen	Slightly soluble fertilizer for high pH Phosphorus soils
Dolomitic container	6 to 14%	Calcium	Pre-sowing incorporation in bareroot seedbeds and growing media limestone
Sul-Po-Mag@; K-Mag®	11%	Sulfur Potassium	A soluble fertilizer that can be used for multiple deficiencies
Magnesium sulfate (Epsom salts)	10 %	Sulfur	Sole source of Mg in custom fertigation solutions for containers. Use as a foliar spray on bareroot stock
Peters Excels "Cal-Mag"	2%	All except Sulfur	Container seedling fertigation
Peters Excel® "Magnitrate"	9%	N+Micros	Container seedling fertigation

sure that they contain magnesium. Heavy nitrogen fertilization, especially with ammonium forms of nitrogen, can induce deficiencies of magnesium. Limiting ammonium nitrogen to 25% of the total nitrogen supply is recommended, especially under low light conditions.

* **In bareroot nurseries, apply fertilizers or amendments containing magnesium if warranted.** If a magnesium deficiency is suspected, then the best type of fertilizer will depend on the soil pH. Dolomitic limestone is usually all that is needed in acidic soils but, in neutral or alkaline soils, specialized magnesium fertilizers are available (Table 2). Epsom salts ($MgSO_4$) are a very soluble fertilizer that can be applied anytime during the season as a foliar spray. Sul-Po-Mag® is another soluble source of magnesium that also supplies sulfur and potassium.

In conclusion, magnesium is a critical mineral nutrient that can be easily overlooked in normal fertilization programs. Remember that nutrient ratios with calcium and potassium can be as important as the actual concentration of magnesium itself. Annual soil tests will tell bareroot nurseries whether they need to lime their soils, as well as the rates of dolomitic limestone to be used. Container growers should include magnesium in their fertigation solutions, rather than rely on incorporated dolomite in growing media.

Sources:

Benzian, B. 1965. Experiments with nutrition problems in forest nurseries. Forestry Commission Bulletin No. 37. London: Her Majesty's Stationery Office. 251 p.

Brown, W. 1987. Crop nutrition and media analysis. Canadian Florist, Greenhouse & Nursery. December, 1987.

Jones, U.S. 1982. Fertilizers and soil fertility. Reston, VA: Reston Publishing Company. 421 p.

Landis, T.D.; Tinus, R.W.; McDonald, S.E.; Barnett, J.P. 1989. Seedling nutrition and irrigation, Vol. 4, The Container Tree Nursery Manual. Agric. Handbk. 674. Washington, DC: USDA, Forest Service. 119 p.

Marschner, H. 1986. Mineral nutrition of higher plants. San Diego, CA: Academic Press, Inc. 674 p.

Mengel, K.; Kirkby, E.A. 1979. Principles of plant nutrition. Bern, Switzerland: International Potash Institute. 593 p.

Palomaki, V. 1995. Effects of magnesium deficiency on needle ultrastructure and growth of Scots pine seedlings. Can. J. For. Res. 25 (11): 1806-1814.

Parnes, R. 1990. Fertile soil: a grower's guide to organic and inorganic fertilizers. Davis, CA: agAccess. 190 p.

Ylimartimo, A.; Paakkonen, E.; Holopainen, T.; Rita, H. 1994. Unbalanced nutrient status and epicuticular wax of Scots pine seedlings. Can J. For. Res. 24 (3): 522-532.

Errata: In the January, 1996 issue, I said that the Peters Excel@ line of fertilizers contains calcium, but not all formulations do. What is unique is that they are compatible with other calcium fertilizers so that solubility in the stock solutions is not a problem.

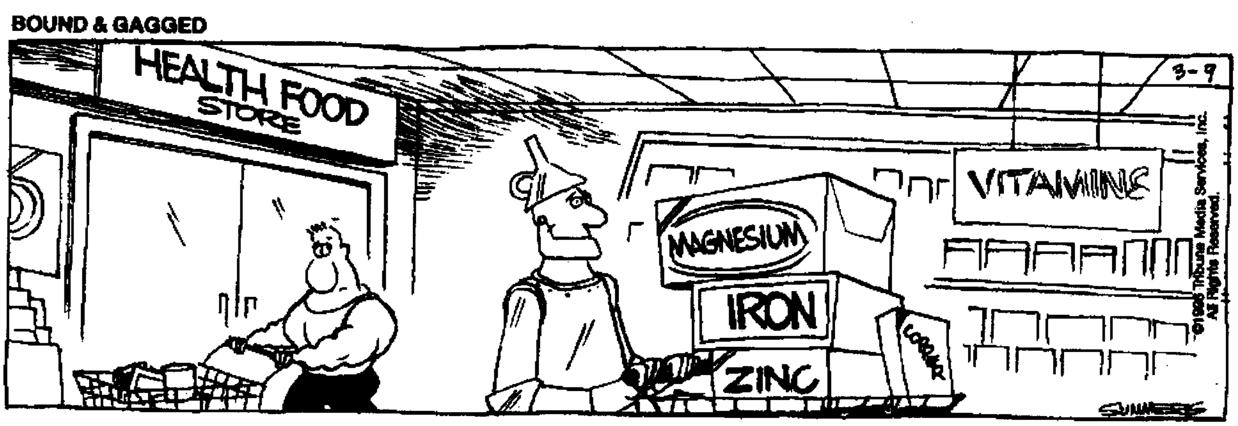


Figure 3. Even the tin man had enough sense to know that secondary mineral nutrients are important to good nutrition.

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