Soil and Fertilizer Magnesium

12
Mg
24.31

By Robert Mikkelsen

Magnesium (Mg) is an essential plant nutrient that is too frequently overlooked. Although weathering of primary and secondary minerals may provide adequate Mg in some soils, there are some soils that benefit from Mg additions. There are various soluble and slowly soluble Mg sources available to meet crop demands.

Magnesium is a common constituent in many minerals, comprising 2% of the Earth's crust. It is also a common component in seawater (1,300 ppm). Magnesium is present in the divalent Mg^{2+} form in nature, but can be processed into a pure metal. Since metal Mg is one-third lighter than aluminum (Al), it is commonly used in lightweight alloys for aircraft and automobiles. In the powder or ribbon form, metallic Mg burns when exposed to air. China is the largest producer of Mg metal, although the USA and the former Soviet Union (FSU) also produce significant amounts.

The importance of Mg for human and plant nutrition has been well established. This article will review the behavior of Mg in rocks and soils, and describe some of the common Mg sources used for plant nutrition.

Magnesium in Primary and Secondary Minerals

Several ferromagnesian minerals (such as olivine, pyroxene, amphibole, and mica) are major Mg sources in basic igneous rocks. Secondary minerals, including carbonates... for example, dolomite [$MgCO_3 \cdot CaCO_3$], magnesite [$MgCO_3$], talc [$Mg_3Si_4O_{10}(OH)_2$], and the serpentine group [$Mg_3Si_2O_5(OH)_4$] ...are derived from these primary minerals.

When serpentine is present in large amounts, it gives rise to the term "serpentine soil." In these ultramafic serpentine soils, high Mg concentrations lead to poor plant growth and poor soil physical conditions. Undesirably high concentrations of nickel may also occur in these soils.

These primary and secondary minerals are important sources of Mg for plant nutrition, especially in unfertilized soil. But plant-available Mg concentrations cannot be accurately predicted based only on the parent material composition due to differences in mineral weathering rates and leaching. In some cases, the contribution of minerals to meeting the entire crop demand for Mg during a single growing season is insufficient to prevent plant and animal deficiencies.

Non-Exchangeable and Exchangeable Magnesium

Magnesium is located both in clay minerals and associated with cation exchange sites on clay surfaces. Clays such as chlorite, vermiculite, and montmorillonite have undergone intermediate weathering and still contain some Mg as part of their internal crystal structure. The Mg release rate from these clays is generally slow. Illite clays may also contain Mg, but their release rate is even slower. The details of clay weathering and mineralogy are available elsewhere.

The gradual release of non-exchangeable Mg has been demonstrated in a variety of conditions, but the amount of Mg dissolved from these minerals is often small compared with the amounts required to sustain high crop yields for multiple years. This non-exchangeable Mg may be coming from the octahedral clay layers as well as the interlayer material. In low-productivity agriculture, this slow release of Mg may be sufficient to replenish the soil solution and meet plant nutritional demands.

Abbreviations and notes: N = nitrogen; Ca = calcium; K = potassium; S = sulfur; ppm = parts per million.

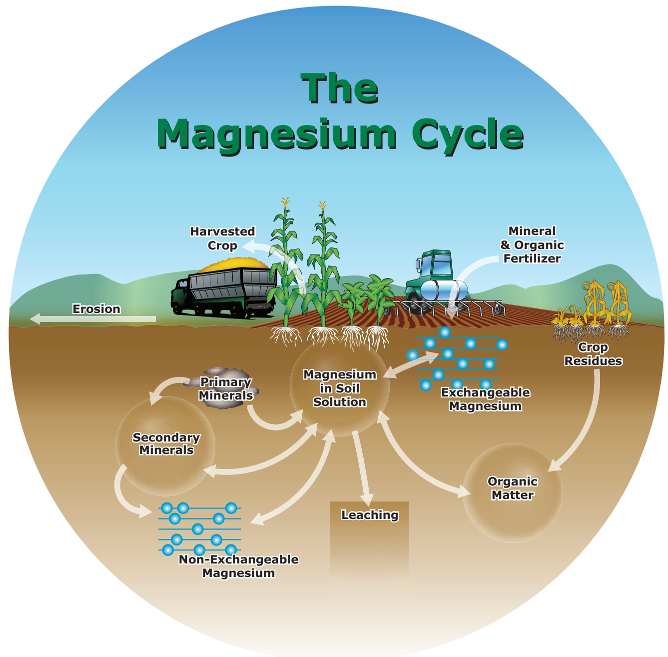

Figure 1. Magnesium cycling in agricultural soils.

In alkaline to slightly acidic soils, Mg is usually second in abundance to Ca on cation exchange sites. Magnesium ions generally resemble Ca in their behavior in ion exchange reactions. These cation exchange reactions are generally reversible, where even strongly adsorbed cations can be typically replaced by manipulation of the soil solution.

To become soluble, Mg adsorbed on a clay particle must be replaced by a cation present in the soil solution. Cation exchange reactions are stoichiometric, meaning that the charge balance must be maintained. For example, two K^+ ions are required to replace a single Mg^{2+} ion. The exchange reactions are very rapid, but the limiting step is usually the diffusion of the cation to or from the colloid exchange site.

Certain clays, such as vermiculite, have a special affinity for soluble Mg. The hydrated Mg ion fits well between the partially expanded sheets of vermiculite, making this clay an excellent Mg scavenger.

An excessively large proportion of Mg on the cation exchange sites can lead to degradation of the soil physical condition. Since Mg cations have a larger hydrated radius than Ca, the attractive forces that tend to aggregate soil colloids in typical conditions are diminished with an over-abundance of

Mg. A high proportion of Mg on soil exchange sites results in dispersion of clay particles, leading to decreased porosity and reduced infiltration rates typically found in serpentine soils.

Pathways of Magnesium Loss

When removal of Mg from the soil is greater than the release rate of Mg from mineral sources and fertilizer additions, Mg concentrations in solution and on the exchange sites will decline. This low-Mg situation is most frequently observed on sandy soil with low exchangeable Mg, soils receiving repeated applications of calcitic limestone, and due to a competition with other cations, such as K. Long-term sustainability requires balancing the Mg supply with removal from crop harvest, leaching, and runoff.

Crop removal A wide range of Mg crop removal data exists in published literature, depending on the soil Mg supply, growing conditions, the specific plant species, and yield levels. For example, a high-yielding crop of sugarbeets may take up as much as 80 lb Mg/A, and high-yielding forages and corn silage may remove 50 lb Mg/A. In general, cereal crops remove smaller amounts of Mg at harvest compared with root crops and many fruit crops. Of all the pathways of loss, removal of abundant crops at harvest is the desired outcome.

Leaching Losses Loss of soil cations through leaching can result in significant decline in nutrient availability over time. The extent of Mg loss from the rootzone to lower soil horizons will vary greatly depending on the soil properties, the amount of water passing through the soil, and local conditions. In some circumstances, leaching losses as low as a few pounds of Mg/A/yr are reported. However in other conditions, losses exceeding 100 lb Mg/A/yr are not unusual.

Fertilization with other cations, such as K^+ and Ca^{2+}, frequently leads to enhanced Mg solubility in the soil as they exchange on the clay sites and ultimately make Mg more susceptible to leaching. Decreases in exchangeable Mg are often correlated with the amount of salts added as fertilizer or soil amendments. In soils where Ca and Mg are leached following repeated K fertilization, an undesirable enrichment of K on the cation exchange sites can result. Leaching losses of nitrate accelerate Mg loss, especially under urine and dung spots in pasture.

Erosional Loss The soil surface is the zone that generally contains the most organic matter and essential plant nutrients. Runoff water leaving the field may carry with it valuable organic matter and nutrients associated with the eroding clay. Minimizing water runoff from fields by use of conservation techniques such as vegetative buffers or irrigation tailwater return will help reduce losses of Mg, as well as protect adjacent surface water.

Interactions Magnesium deficiencies are not uncommon in low pH, sandy soils where Al dominates the soil cation exchange sites. Magnesium assimilation is also depressed in the presence of Al^{3+}, which has a detrimental effect on root growth as well as through a competitive cation effect for root uptake.

High exchangeable K concentrations can have an adverse effect on Mg availability for plants. The competition between these two cations for root uptake appears to be the primary cause, although high K may also impair Mg translocation within the plant. Low forage Mg concentrations following K fertilization have been linked with low Mg in the blood of grazing animals (called grass tetany) where it is essential for certain enzyme and metabolic reactions.

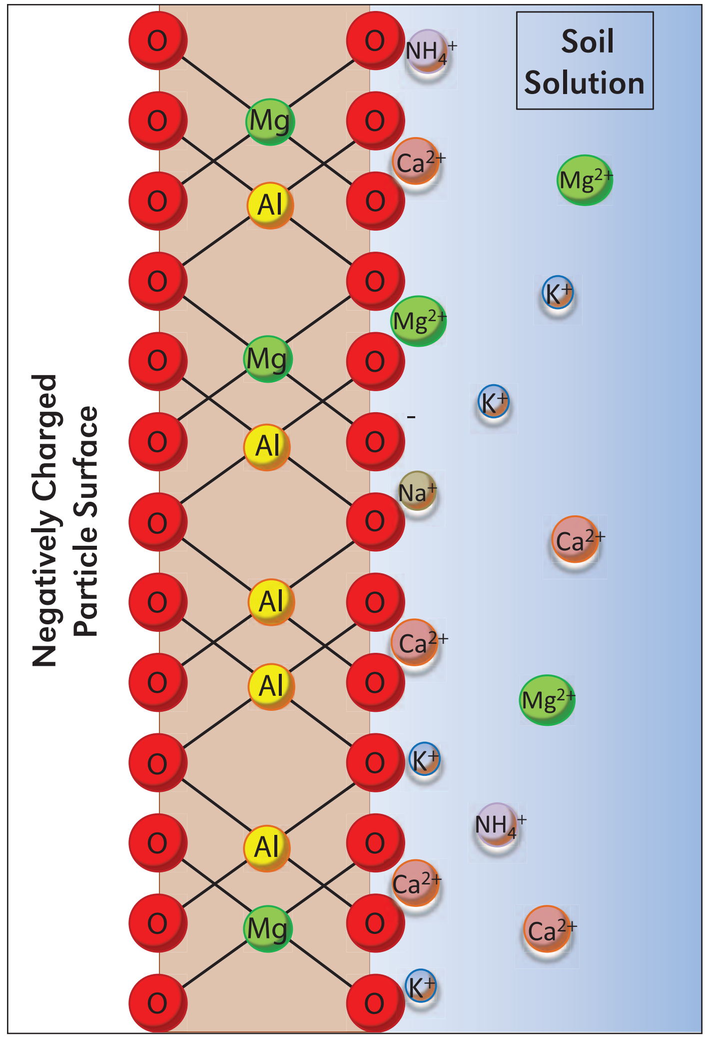

Figure 2. Common 2:1 clays contain Mg as a constituent of their clay structure, in the interlayer region, and as exchangeable cations on the clay edges.

Magnesium Sources

There are many excellent sources of Mg that can meet crop demands. Surface placement of the soluble Mg sources is usually satisfactory, but incorporation of the less-soluble Mg materials into the soil is recommended. Since there are no serious environmental issues associated with agricultural uses of Mg, no special precautions are needed. Contributions of Mg in rainfall are generally less than one lb/A/yr.

Common Mg fertilizers are typically divided into two classes: soluble sources and semi-soluble sources. The particle size of semi-soluble Mg sources in large part determines the rate of dissolution, while this factor is not significant for the soluble sources.

Soluble Mg Sources (with approximate solubility at 25°C)

Kieserite – $MgSO_4 \cdot H_2O$; 17% Mg – Kieserite is the monohydrate of magnesium sulfate, produced primarily from mines located in Germany. As a carrier of both Mg and S, kieserite finds multiple applications in agriculture and industry (360 g/L)

Kainite – $MgSO_4 \cdot KCl \cdot 3H_2O$; 9% Mg – Kainite is the mixed salt of magnesium sulfate and potassium chloride. It is

IPNI Awards Available to Graduate Students and Scientists in 2010

Each year, IPNI offers the Scholar Award to honor and encourage deserving graduate students, and also the IPNI Science Award to recognize and promote distinguished contributions by scientists.

"We receive very favorable reaction to these awards each year and they clearly have many positive benefits," said IPNI President Dr. Terry Roberts. "It is important to encourage talented young people in their studies of agronomic and soil sciences, while established scientists also deserve recognition for career accomplishments. These awards are made possible by our member companies and are evidence of their respect for science."

The Scholar Award requires students who are candidates for either a M.S. or Ph.D. degree in agronomy, soil science, or related fields to submit an application and supporting information by June 30. Individual graduate students in any country where an IPNI program exists are eligible. Only a limited number of recipients are selected for the award, worth US$2,000 each. The application process is available online only. Recipients are announced in September.


Description and Nomination Format for the
IPNI
Science Award
A Program of the
International Plant Nutrition Institute (IPNI)
IPNI
Nomination deadline: September 30, 2010
Award announcement date: December 1, 2010

The Science Award goes to one individual each year, based on outstanding achievements in research, extension, or education which focus on efficient and effective management of plant nutrients and their positive interaction in fully integrated crop production, enhancing yield potential and/or crop quality. It requires that a nomination form (no self-nomination) and supporting letters be submitted by mail before September 30. The Award announcement is December 1. It includes a monetary prize of US$5,000.

More information about past winners of these awards, plus details on qualifications and requirements for both awards, can be found at the IPNI website: >www.ipni.net/awards<. BC

Magnesium...from page 27

most commonly used as a K source, but is useful where both Mg and K are required (variable solubility).

Langbeinite – $2MgSO_4 \cdot K_2SO_4$; 11% Mg – A widely used source of Mg, as well as K and S, this mineral is an excellent multi-nutrient source. While totally soluble, langbeinite is slower to dissolve than some Mg sources and not typically delivered through irrigation systems (240 g/L).

Magnesium Chloride – $MgCl_2$; 25% Mg – Generally sold as a liquid due to its high solubility, this material is frequently used as a component in fluid fertilizers (560 g/L).

Magnesium Nitrate – $Mg(NO_3)_2 \cdot 6H_2O$; 9% Mg – Widely used in the horticultural industry to supply Mg in a form that also provides a soluble N source (1,250 g/L).

Magnesium Sulfate (Epsom salt) – $MgSO_4 \cdot 7H_2O$, 9% Mg – Epsom salt derives its name from naturally occurring geologic deposits in Epsom, England. It is a common mineral and a byproduct from various brines that makes an excellent Mg source. It is similar to Kieserite, except it contains seven water molecules associated with the $MgSO_4$ (357 g/L).

Schoenite – $K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$; 6% Mg – Although more commonly used as a K source, it is also a useful soluble Mg fertilizer material (330 g/L).

Animal Wastes and Composts The concentration of Mg in these organic materials is low compared with mineral sources. However, high application rates can supply significant quantities of Mg to the soil. Magnesium in these materials is generally considered to be totally plant available within a growing season.

Foliar Sprays These may contain one or more of the soluble Mg materials discussed above. Specialty materials containing EDTA, lignosulfonate, and other complexing agents may be used with soluble Mg sources to improve foliar uptake. Leaf sprays are effective at correcting Mg deficiency, but they generally must be repeated to maintain maximum plant growth and are usually considered a temporary resolution before the soil can be modified.

Semi-Soluble Mg Sources

Dolomite – $MgCO_3 \cdot CaCO_3$; 6 to 20% Mg – Depending on the geologic source, the concentration of Mg will vary considerably. Pure dolomite contains 40 to 45% $MgCO_3$ and 54 to 58% $CaCO_3$. However a concentration of 15 to 20% $MgCO_3$ (4 to 6% Mg) is common for material called "dolomitic limestone". Dolomite is often the least expensive common source of Mg, but may be slow to dissolve, especially where soil acidity is lacking.

Hydrated dolomite – $MgO \cdot CaO/MgO \cdot Ca(OH)_2$;18 to 20% Mg – This product is made by heating dolomitic lime (calcined) to form MgO and CaO. It is then hydrated to form dolomitic hydrated lime, which may contain only hydrated calcium oxide or it may also contain hydrated magnesium oxide. These compounds dissolve faster than untreated dolomite.

Magnesium oxide – MgO; 56% Mg – Composed of only magnesium and oxygen, it is formed by heating $MgCO_3$ to drive off carbon dioxide. It contains the highest concentration of Mg of common fertilizers, but is rather insoluble. Applying in advance of plant demand and using a fine particle size will help make this nutrient source useful for plant growth.

Struvite – $MgNH_4PO_4 \cdot 6H_2O$; 10% Mg – Struvite is produced primarily during the recovery of P in wastewater from animal manure and municipal treatment plants. While slow to dissolve, struvite also provides a valuable supply of N and P, nutrients not found in other Mg-containing fertilizers

Crop fertilization practices continue to intensify with the demand for high yields. Magnesium is an essential plant nutrient that is frequently overlooked and may be limiting plant growth. Soil testing should be used to identify potential deficiencies, and there are many excellent Mg sources available for farmers when needed. BC

Dr. Mikkelsen is IPNI Western North America Regional Director, based at Merced, California; e-mail: rmikkelsen@ipni.net.