# Site-Specific Nutrient Management

For Nutrient Management Planning To Improve Crop Production, Environmental Quality, and Economic Return

## Calcium and Magnesium: Chapter 6 of 10

Written By:

**Agustin Pagani**, Post-Doctoral Fellow
**John E. Sawyer**, Professor
**Antonio P. Mallarino**, Professor
Department of Agronomy, Iowa State University

Developed in cooperation with:
**Lara Moody**, The Fertilizer Institute (TFI)
**John Davis**, Natural Resources Conservation Service (USDA-NRCS)
**Steve Phillips**, International Plant Nutrition Institute (IPNI)

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# Chapter 6:

## Calcium and Magnesium Management

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## Introduction

Calcium (Ca) and magnesium (Mg) are considered secondary macronutrients because they are less commonly yield limiting than the macronutrients (N, P, and K), yet are required by crops in relatively large amounts. Calcium and Mg occur in the soil as soluble ‘divalent’ (‘double-charged’) cations ($Ca^{2+}$ and $Mg^{2+}$), on cation exchange sites, and in primary minerals. The major processes in Ca and Mg cycling are plant uptake, exchange, precipitation, weathering, and leaching. Calcium and Mg dynamics in the soil are quite similar to K. Like K, plants absorb the soluble ionic forms from soil solution ($Ca^{2+}$ and $Mg^{2+}$), which is then replenished from exchangeable and mineral Ca and Mg. The most notable difference between the Ca and Mg nutrient cycles and K is the absence of clay fixation with Ca and Mg.

### Calcium as an Essential Nutrient

Calcium is essential for plant growth, cell division, and cell enlargement. It is a component of cell membranes and is important for developing the root system, shoot tips, and storage organs. Calcium aids in pollen development and helps plants retain foliage. Calcium strengthens cell walls, helping to reduce bruising and plant disease. An adequate supply of Ca produces food crops which are less susceptible to handling damage and have a longer shelf life. Fruit and vegetables will also have a higher nutritional value. Crops deficient in Ca can have growth disorders. Since Ca does not move readily within the plant, Ca deficiencies appear in the younger tissues. Calcium deficiencies may result in the death of the plant’s growing point. It may also cause blossoms and buds to drop prematurely. Calcium quantities in the harvested portions of common agricultural crops are presented in Table 1.

Calcium is usually the dominant basic cation in soil cation exchange reactions, typically accounting for more than 70% of base saturation. Base saturation represents the percentage of the cation exchange capacity (CEC) occupied by basic cations (Ca, Mg, K, and Na), and increases with increasing soil pH. Exchangeable Ca exists in equilibrium with the soil solution, replenishing soluble Ca used by plant uptake or lost by leaching. Leaching can be significant in coarse-textured soils where substantial water moves through the profile. The formation of many calcareous soils occurred by Ca accumulation with leaching from the topsoil, soil developed from calcium carbonate ($CaCO_3$) parent material, or carbonates deposited as water carrying dissolved carbonates accumulated in low landscape areas and then water evaporated leaving the solid carbonaceous materials. These Ca-rich ‘calcic’ areas can be comprised $CaCO_3$ or gypsum ($CaSO_4$). Calcium is made available to plants by dissolution of these minerals or in the long term through weathering of primary minerals such as feldspars and micas.

A low exchangeable Ca content in soil often causes acidity problems due to low base saturation, before actual Ca nutrient deficiency becomes an issue. Where soil acidity is a problem, liming soils with limestone ($CaCO_3$ and $MgCO_3$) is a common practice and thus supplies plant available Ca. Soils with neutral to basic pH are buffered at high pH levels by both Ca on the exchange complex (as the dominant part of the base saturation) and Ca in bicarbonates and carbonates (free lime).

Because of its divalent ($2^+$) charge, Ca acts as an ionic ‘glue’ (electrostatic attraction with negatively charge clay particles), thus promoting aggregation of soil particles through a process called flocculation. Soils with high levels of sodium (Na), referred to as sodic soils, promote dispersion which is the opposite of flocculation. When the monovalent (single-charged) $Na^+$ ions reach a high proportion of the cations on clay negative exchange sites (the CEC), the weak (and single) positive charge of the $Na^+$ ion is not strong enough to overcome the negative charges of clay particles, which then repel each other. The result of dispersion is a structureless soil with insufficient aeration, permeability, and water-holding capacity for optimum plant growth. Additions of Ca in the form of gypsum are frequently used for reclaiming sodic soils because it counters the effects of Na by adding $Ca^{2+}$ ions, exchanging $Ca^{2+}$ for $Na^+$ on the soil exchange site, allowing leaching of Na from the soil, and thus promoting aggregation critical for soil productivity. Gypsum is used instead of lime as the Ca source as often soil pH does not need to be increased, which does not occur with gypsum application.

## Magnesium as an Essential Nutrient

Magnesium plays a critical role in nearly all parts of plant metabolism and protein synthesis, is an activator of enzymes, and an essential constituent of chlorophyll. It also aids in the formation of sugars, oils and fats. Deficiency in Mg leads to reduced photosynthesis, which limits crop yields. Plants require less Mg than Ca, but deficiencies are more common because less Mg exists in the soil solution and on the soil exchange complex. Magnesium deficiency usually appears on older plant leaves first; the leaf tissue between the veins turns yellow or reddish in color, while the veins remain green. Severe deficiencies will cause leaf margins to curl. Magnesium quantities in the harvested portions of common agricultural crops are presented in Table 1.

Mineral forms of Mg are relatively resistant to weathering and represent a large fraction of total soil Mg. These include biotite, horneblende, olivene, and most 2:1 clay minerals. Magnesium can also be present in calcareous surface and subsurface soils as magnesium carbonate ($MgCO_3$), frequently along with $CaCO_3$. Although Ca and Mg share the same exchange processes, Mg sorbs less strongly than Ca to soil colloids (still Mg sorbs much more strongly than monovalent cations) and therefore is more prone to leaching, particularly in sandy soils. As a divalent cation, $Mg^{2+}$ competes with $Ca^{+2}$, $K^+$, and $NH_4^+$ for plant absorption and cation exchange sites. As with Ca, Mg helps with soil flocculation and soil structure, but to a lesser extent. Magnesium deficiencies generally occur when the other cations dominate the soil exchange complex along with low Mg concentrations. A common Mg deficiency problem in cattle is called grass tetany, or hypomagnesaemia. This deficiency is due to insufficient Mg in forage fed to livestock. Often feeds are supplemented with Mg salts to supply adequate Mg. In soils with low available Mg, lime application to acidic soils (except with pure calcitic lime) often supplies adequate Mg (as the $MgCO_3$ component of lime along with $CaCO_3$); or fertilizers are applied such as potassium-magnesium-sulfate and epsom salt ($MgSO_4$) if soil pH is already at adequate levels. Magnesium concentration in forages can also be reduced when high rates of K are applied, increasing the chance of low forage Mg levels and development of grass tetany.

*Table 1. Calcium and magnesium quantities in harvested portions of common agricultural crops.*

| Crop | Unit of Yield | Pound of Ca per unit of yield | Pound of Mg per unit of yield |
|---|---|---|---|
| Corn | bu | 0.01 | 0.05 |
| Soybean | bu | 0.18 | 0.18 |
| Oat and Straw | ton | 4 | 4 |
| Wheat | bu | 0.03 | 0.15 |
| Barley | bu | 0.03 | 0.05 |
| Alfalfa | ton | 28 | 5 |
| Clover | ton | 28 | 7 |

*Adapted from Modern Corn and Soybean Production. 2000. MCPS Publications.*

## Calcium and Magnesium Soil Testing

An often used approach for determining if the soil supply of Ca and Mg is sufficient to meet crop needs is to extract soil with ammonium acetate or Mehlich-3 (the same procedures used to determine soil test K) and evaluate the amount measured against critical levels. Because most U.S. soils contain more than adequate levels of Ca and Mg for most crops, no reliable or generally accepted critical level has been established. Therefore, although an estimate of exchangeable Ca and Mg sometime is routinely measured, many universities do not publish soil test Ca or Mg interpretations. There are exceptions, and an example is Ca testing for potato production due to issues with tuber density. Another example would be soil testing to help avoid development of grass tetany, where knowledge of soil test Mg and K would be useful when high rates of K are needed. Also, soils typically have large available levels of both nutrients because Ca and Mg are replenished by limestone application. If someone is interested in the soil CEC level, then routine soil testing can be used to estimate CEC by summing the dominant exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$, $H^+$, $Na^+$).

The Ca:Mg ratio or the basic cation saturation ratio concepts (meq/100g charge concentration based ratio) was developed many years ago as a means to identify an optimal level of these two nutrients or other cations for crop production. However, numerous research studies have shown that the Ca:Mg ratio or ratios of several cations is not a viable basis for fertilization with Ca, Mg, or other cations. Having sufficient levels of exchangeable Ca and Mg (through soil testing) is the proper method of evaluation where reliable field calibrations are available, rather than trying to manipulate ratios. Fortunately, in most U.S. soils Ca and Mg levels are adequate and the ratio of these nutrients are not an issue for availability of either nutrient as the parent material the soil developed from or local limestone sources supply both nutrients in adequate proportions. Also, adequate levels of plant-available Ca and Mg are maintained without need for fertilization either because the soil has a large inherent supply capacity or because of liming to maintain adequate soil pH for crop production.

## Calcium and Magnesium Sources and Application

Application of Ca and Mg occurs most commonly through liming practices. With limestones classified as either calcitic or dolomitic, there is application of both Ca and Mg as these are contained in all limestones. Therefore, as long as acidic pH problems are corrected through liming, Ca and Mg supply will be maintained and at amounts more than removed with crop harvest. Once removal has occurred with years of crop production, and with concurrent low soil pH, liming once again supplies needed Ca and Mg. Soils that have naturally high pH (neutral to basic pH), and those with free lime (calcareous), have more than adequate levels of these nutrients.

Even though limestone is the main source of Ca and Mg for crops, there are several fertilizers or amendments that contain these nutrients. Table 2 presents the most common sources of Ca and Mg. Within this list, limestone requires a special consideration since it is never a pure material but a mixture of Ca and Mg carbonates (with higher Ca concentration in the calcitic limestone and higher Mg concentration in the dolomitic limestone). Therefore limestone, no matter the type, is a source of both Ca and Mg.

*Table 2. Most frequently used calcium and magnesium sources.*

| Source | Formula | Element concentration) |
|---|---|---|
| *Calcium* | | --- % --- |
| Calcium chloride | $CaCl_2$ | 36 |
| Calcitic limestone | $CaCO_3$ | Approx. 32 |
| Dolomitic limestone | $CaCO_3 + MgCO_3$ | 21 to 30 |
| Gypsum | $CaSO_4 \bullet 2H_2O$ | 50 |
| *Magnesium* | | |
| Dolomitic limestone | $CaCO_3 + MgCO_3$ | 6 to 11 |
| Magnesium sulfate | $MgSO_4 \bullet H_2O$ | 17 |
| Potassium magnesium sulfate | $K_2SO_4 \bullet 2MgSO_4$ | 11 |

## Summary

Secondary nutrients such as Ca and Mg are no less essential to plant growth than the primary nutrients. However, the mineralogy and texture of many U.S. soils maintain high levels of available Ca and Mg. An exception would be sandy soils in association with fertilization need of certain crops, for example potato, or interaction with application of other nutrients like K. Because plants require relatively small amounts of these nutrients and leaching is a minor loss, Ca and Mg deficiencies are rare but do occur in specific soil conditions and crops. In addition, liming soils to neutralize acidity and increase soil pH also add plant available Ca and Mg, thus reducing the probability of deficiency and need for fertilizer application.