4 Calcium and Magnesium

Charles S. Wortmann
UNL Professor of Agronomy

Revised from:
Kenneth D. Frank
UNL Associate Professor Emeritus, Agronomy

Calcium (Ca) and magnesium (Mg) are secondary nutrients, but they are secondary only in the probability of deficiencies, and plants require them in quantities similar to phosphorus (P).

The range of calcium and magnesium in plant tissue will vary considerably within a given crop and among crops as shown in Table 4-1. Generally wide variation in the same plant species occurs because varieties differ in the amount of nutrients they take up. The different suggested levels of sufficiency among states is generally due to soil differences (Table 4-1). For example, the range of calcium and magnesium for soybean in Nebraska is considerably higher than in Georgia, because most Nebraska soils, especially subsoils, are high in calcium and magnesium, while Georgia soils tend to be acid and have acid subsoils.

Table 4-1.

Concentration range for calcium and magnesium in plant tissue at different plant growth stages for various crops.

Crop	Plant Part	Calcium		Magnesium	
		Nebraska[1]	*Georgia*[2]	*Nebraska*	*Georgia*
		percent			
Wheat	Whole plant at boot stage	0.3 - 2.5	0.2 - 0.5	0.12 - 0.8	0.15 - 0.5
Grain Sorghum	3rd leaf from top, boot stage	0.15 - 0.3		0.1 - 0.2	
Corn	Ear leaf, early silk	0.2 - 0.6	0.25 - 0.5	0.15 - 0.3	0.13 - 0.3
Alfalfa	Top 6-inch, early bloom	1.8 - 3.0	0.8 - 3.0	0.3 - 1.0	0.25 - 1.0
Soybeans	Newest mature trifoliate leaf from top	1.2 - 2.5	0.5 - 1.5	0.3 - 1.0	0.25 - 0.8

Sources:
[1]Wiese, R.A. Plant Tissue Analysis; Capabilities and Limitations. University of Nebraska, Department of Agronomy, Lincoln, NE.
[2]Plank, C.O. Plant Analysis Handbook for Georgia. University of Georgia, Athens, Cooperative Extension, Athens, GA.

Availability of Calcium and Magnesium to Plants from Soil

Calcium and magnesium, like potassium (K), are positively charged ions (cations) held to the surface of clay and organic matter in the soil by electrostatic charge. These cations are exchangeable because they exchange with cations in the soil solution. The total number of charges on the soil complex is the cation exchange capacity (CEC) of the soil. It is expressed in units of milliequivalent per 100 grams of soil (meq/100g).

Because calcium and magnesium are only available to plants in the exchangeable form, soil tests measure only exchangeable calcium and magnesium.

Plants take up almost all calcium and magnesium though mass flow rather than by root interception. With root interception, the exchange of calcium and magnesium takes place when the root grows in close proximity to clay and organic matter particles holding cations. With mass flow, calcium and magnesium on the exchange sites exchange with other cations in the soil solution. As plants transpire water, the soil solution moves the calcium and magnesium to the roots. Considerably more calcium and magnesium moves to roots by mass flow than plants actually take up.

Do ideal Ca:Mg:K ratios exist in soil?

Scientists first studied the concept of an ideal ratio between calcium, magnesium, and potassium in 1901 while producing tomatoes on sandy soil. They considered using ratios of *total* calcium, magnesium, and potassium. However, they quickly recognized that total amounts were not a good indicator of available nutrients to plants. Therefore, they used exchangeable (extractable) levels of calcium, magnesium, and potassium. Early work in New Jersey determined that an "ideal alfalfa soil" should have a 65-10-5-20% saturation of calcium, magnesium, potassium, and hydrogen (H) respectively.

The pure ratio concept is very misleading. A Ca:Mg ratio of 5:1 is a statement of relative proportions of available calcium to magnesium. Two soils, one with 100 and 20 parts per million (ppm) of available calcium and magnesium and the other with 300 and 60 ppm available calcium and magnesium respectively, both have the same 5:1 ratio. However, the first soil would be marginally low to deficient while the second soil would have adequate amounts of both calcium and magnesium.

Scientists have conducted considerable research on calcium, magnesium, and potassium saturation percentages in soil since the 1901 New Jersey experiments. Some of those researchers include Allaway (1945), Bear, et al. (1945), Eckert and McLean (1981), Hunter (1949), McLean, et al. (1983), Simson, et al. (1979), Schulte and Kelling (1985) and Schulte, et al. (1987).

Research Summary

1. Total soil calcium, magnesium, or potassium content is not a good measure of availability to plants.
2. Exchangeable calcium, magnesium, and potassium are good estimates of the soil's ability to provide these nutrients to plants; however, optimum yields can be produced across a wide range of calcium, magnesium, and potassium ratios in soil. Parent minerals and soil texture greatly influence saturation percentages for calcium, magnesium, and potassium by influencing cation exchange capacity.

a. Under Nebraska conditions, on soils with a pH of 7.3 or lower (and no excess free lime) the sufficient saturation ranges are shown in Table 4-2.

Table 4-2.

Acceptable saturation ranges for exchangeable calcium, magnesium, and potassium and suggested minimum soil test levels for non-calcareous soils.

	Acceptable Saturation	**Minimum Soil Test Levels**
	percent	*ppm*
Calcium[1]	50 to 70	—
Magnesium	10 to 35	50
Potassium[2]	2 to 5	120

[1]For Nebraska soils, yield response at as low as 40% Ca saturation would not be expected unless the low Ca saturation is associated with low soil pH. Lime should be applied to correct soil pH.
[2]Experiments on some sandy soils in Nebraska have shown no response to potassium at soil test values of 80 ppm exchangeable K.

b. Excess levels of potassium can alter the saturation percentage of magnesium, especially on sandy soils lower in CEC than silt and silty clay loam soils (Table 4-3).

c. Adding an excess amount of magnesium does not appreciably change the potassium saturation percentage (Table 4-3); however, the calcium saturation percentage can be changed by excessive amounts of potassium and magnesium.

d. The percent saturation for the Ortello soil in Table 4-3 adds up to more than 100 because the soil is slightly calcareous. The Crete and Hall soils are acid; consequently, their saturation percentages are less than 100 because of hydrogen on the exchange sites. The zero pounds of magnesium and 2,560 pounds of potassium per-acre treatment decreased corn yield on the Ortello soil in 1973, but it did not decrease corn yield on the Crete and Hall soils even though the Mg:K ratios were 0.8, 0.8, and 0.9 for the Ortello, Crete and Hall soils respectively. McLean et al. (1983), also reported reduced corn yield when sufficient potassium was added to decrease the Mg:K ratio.

e. Saturation percentages of calcium were not changed uniformly across the three soils in Table 4-3; however, yields over the three-year period for these experiments were not influenced by changes in the saturation percentage of calcium, potassium and magnesium (as long as the levels were in the sufficient range).

TABLE 4-3.

Influence of high rates of potassium and magnesium on the saturation levels of potassium, magnesium, and calcium three years after application on three Nebraska soils with different cation exchange capacities.

Treatment			**Exchangeable Cation**			**Base Saturation**		
Mg	**K**	**CEC**	**K**	**Mg**	**Ca**	**K**	**Mg**	**Ca**
pounds per acre		*meq/100g*	*meq/100g*			*percent*		
Ortello fine sandy loam								
0	0	5.0	0.4	0.9	4.3	8.6	17.6	85.0
0	2,560	4.2	0.7	0.6	3.4	16.0	13.0	80.0
640	0	4.7	0.4	1.5	3.8	8.4	31.6	80.0
640	2,560	5.5	0.8	2.6	3.4	15.0	46.0	61.0
Crete silt loam								
0	0	16.0	1.6	2.5	9.5	10.0	15.2	58.8
0	2,560	16.0	2.6	2.0	7.9	15.8	12.6	48.9
640	0	16.0	1.6	2.7	8.7	9.8	16.6	53.7
640	2,560	16.0	2.8	2.6	7.9	17.4	16.2	49.0
Hall silt loam								
0	0	20.3	1.4	3.1	12.5	6.8	15.0	61.6
0	2,560	20.3	1.9	1.8	13.9	9.4	8.6	68.5

Calcium and Magnesium Deficiency Symptoms

Calcium and magnesium deficiencies in agronomic crops are unlikely in Nebraska. Calcium deficiency has not been documented in the state. Deficiencies of either nutrient are favored by very acid, sandy soils. Magnesium deficiency in corn is expressed as interveinal striping of leaves, with older leaves becoming reddish purple with necrotic margins as magnesium is translocated to newer tissue. Grass tetany in animals is a result of feed or forage which is deficient in magnesium and can be a concern with forage grasses such as fescue. Such deficiency, however, is unlikely in Nebraska.

Depending on the crop, soils in Nebraska should be limed once the pH reaches 5.4 to 5.8. Soils require lime application primarily to address availability of other nutrients, to enhance soil microbial activity, improve legume nodulation, and to eliminate the possibility of aluminum or manganese toxicity, rather than to correct deficiencies of calcium or magnesium.

FIGURE 4-1

Magnesium deficient corn, Nebraska Sandhills, 1996 (organic matter 1%, CEC 8 meq/100g, pH <5.2).

Recommendations for Potassium, Calcium, and Magnesium Ratios in Nebraska

If a calcium deficiency occurs in Nebraska, it is most likely on a sandy soil with an acid subsoil.

Research data do not support the additions of calcium, such as gypsum, or a single source of magnesium, such as magnesium sulfate, to the soil for the purpose of changing the Ca:Mg, the Mg:K or the Ca:K ratios to a preconceived ideal.

In low cation exchange soils, magnesium deficiency may occur if excess potassium, or possibly if excess calcitic lime, is added.

Adding dolomitic lime is preferable to adding calcitic lime to sandy soils because the potential for magnesium deficiency is higher in sands than it is in finer textured soils.

Calcium and Magnesium as Liming Materials

In addition to calcium and magnesium serving as plant nutrients, calcium, primarily, and magnesium, secondarily, are factors influencing soil pH. Under natural processes, hydrogen replaces calcium and magnesium held on clay and organic matter exchange sites. The primary liming materials to correct soil acidity are calcitic or dolomitic limestone. A secondary source of calcium and magnesium is irrigation water. Crop producers should have irrigation water analyzed for nutrients because calcium and magnesium content of groundwater and surface water varies across Nebraska.

Resources

1. Allaway, W. H. 1945. Availability of Replaceable Calcium from Different Types of Colloids as Affected by Degree of Calcium Saturation. Soil Sci. 59:207-217.
2. Bear, F. E., A. Prince, and J. Malcolm. 1945. The Potassium Needs of New Jersey Soils. N. J. Agricultural Experiment Station. Bulletin No. 721.
3. Eckert, D. J., and E.O. McLean. 1981. Basic Cation Saturation Ratios as a Basis for Fertilizing and Liming Agronomic Crops: I. Growth Chamber Studies. Agron. J. 73:795-799.
4. Hunter, A. S. 1949. Yield and Composition of Alfalfa as Affected by Variations in Calcium-Magnesium Ratio in the Soil. Soil Sci. 67:53-62.
5. McLean, E. O., R. Hartwig, D. Eckert, and G. Triplett. 1983. Basic Cation Saturation Ratios as a Basis for Fertilizing and Liming Agronomic Crops. II. Field Studies. Agron. J. 75:635-639.
6. Simson, C. R., R. Corey, and M. Sumner. 1979. Effect of Varying Ca:Mg Ratios on Yield and Composition of Corn *(zea mays)* and Alfalfa (*medicago sativa*). Commun. in soil science and plant analysis, 10 (1&2), 153-162.
7. Schulte, E. E., K. Kelling, and C. Simson. 1980. Too Much Magnesium in Soil? *In* Solutions November/December, 106-116.
8. Schulte, E. E., and K. Kelling. 1985. Soil Calcium-to-Magnesium Ratios—Should You be Concerned? University of Wisconsin-Extension Bulletin No. G2986, Madison, WI.
9. Schulte, E.E., J.B. Peters, and P.R. Hodgson. 1987. Wisconsin Procedures for Soil Testing, Plant Analysis, and Food and Forage Analysis. Department of Soil Science, University of Wisconsin, Madison, WI.

To Table of Contents

Next Chapter