CALCIUM AND MAGNESIUM: THE SECONDARY COUSINS

George Rehm, University of Minnesota

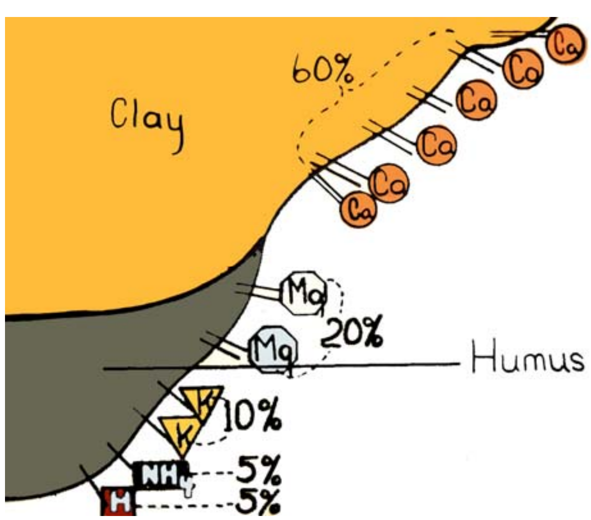
1. Introduction

In the discipline of soil fertility, sulfur (S), calcium (Ca), and magnesium (Mg) are put into the category of secondary nutrients, rather than primary or macronutrients. Frequently, Ca and Mg are grouped with potassium (K) and referred to as the basic cations. Sulfur and K are discussed in separate lessons. This lesson will focus on the importance of Ca and Mg in Minnesota soils and their role in plant nutrition.

At this point, it's important to introduce some chemistry that pertains to reactions of Ca and Mg in soils. Calcium and Mg exist in soils as cations. A cation is an ion with a positive electrical charge. Both Ca and Mg have two positive electrical charges and are written as Ca^{++} and Mg^{++} respectively. The clay-size particles and soil organic matter have negative electrical charges on their surface (refer to the Soil Organic Matter Chapter). There is a fundamental principle of chemistry which states that similar electrical charges repel each other while opposite charges are attracted to each other. So, Ca^{++} and Mg^{++} are attracted to, and are in close association with, negative electrical charges that exist on clay-size and organic matter particles.

The association of cations with both soil and organic matter particles is drawn in Figure 1. This figure intends to show that there is no actual "locking" of cations to soil particles. There is an "association" between a cation with 2 positive charges and 2 negative charges on the soil particle.

Figure 1. A schematic of calcium and magnesium with the negative charges of the clay and humic material. The humus may be viewed as soluble organic matter.



In Figure 1, 60% of the exchange sites are occupied by Ca^{++}, while 20% are occupied by Mg^{++}. The remainder are occupied by K^+ (10%), NH_4^+ (5%) and H^+ (5%). The K^+, NH_4^+ and H^+ are all cations. They have one instead of two positive charges. The percentages in Figure 1 are for illustration purposes only. These percentages can vary over a wide range as will be discussed later.

2. IMPORTANCE IN PLANT GROWTH

2a. Calcium
2b. Magnesium

2a. Calcium

Calcium is part of every plant cell. Much of the Ca in plants is part of the cell walls in a compound called calcium pectate. Without adequate Ca, cell walls would collapse and plants would not remain upright. Calcium is not mobile in plants. It does not easily move from old leaves to young leaves. Deficiency symptoms for Ca are rare in agriculture and a deficiency of this nutrient is not a concern in Minnesota.

Calcium also has a positive effect on soil properties. This nutrient improves soil structure thereby increasing water penetration, and providing a more favorable soil environment for growth of plant roots and soil microorganisms.

Calcium is abundant in all Minnesota soils. The concentration in a form usable by plants may be as low as 300 to 500 ppm in acid soils to more than 7,000 ppm in highly calcareous soils. Calcium is not needed in a fertilizer program. Even at the low levels, there is adequate Ca^{++} for crop growth. When concentrations of Ca are high, free Ca^{++} reacts with phosphate to form insoluble calcium phosphate.

2b. Magnesium

Magnesium is a component of the chlorophyll molecule. Therefore, it is essential for photosynthesis. As might be expected, plants that are deficient in Mg have an overall light green color. In corn, the veins are mainly white when concentrations are inadequate.

In Minnesota, deficiency symptoms in corn and vegetable crops have been observed where soil pH values are very acid (less than 5.0). . Guidelines for the use of Mg in a fertilizer program are listed in Table 1.

Table 1. Guidelines for use of magnesium for production of corn.

Relative Level	Exchangeable Mg	Corn Mg to Apply	Exchangeable Mg	Vegetables Mg to Apply
	ppm	lb. /acre	ppm	lb. /acre
Low	0 to 50	10 - 20 (b)* 50 - 100 (br)	0 to 50	20 (b) 100 (br)
Medium	51 to 150	trial 0	51 to 100	10 (b) 50 (br)
High	151+	0 0	100+	0 0

Source: (3)
*b = band fertilizer; br = broadcast application

The double salt of potassium and magnesium sulfate (0-0-22-22-11) and magnesium sulfate $MgSO_4$ (Epsom salts) are the two choices for application of Mg in a fertilizer program when the results of a soil test indicate a need. Dolomitic lime is also a good source of Mg. The concentration ranges from 8% to approximately 11% Mg. For fields that have been limed with dolomitic limestone, there should be no need to supply Mg in a fertilizer program.

3. CALCIUM AND MAGNEISUM BALANCE

3a. Ratio is not Constant in Soils

The term, “balance”, is frequently over used in the discipline of soil fertility. There are some who believe that there is an actual “balance” between Ca and Mg in soils that has an impact on crop yield. This “balance” is frequently referred to as “cation ratios”. Following this thinking, there is a belief that if a ratio of Ca to Mg is not in an ideal range, plant growth or crop yields will be negatively affected.

Looking to Figure 1, Ca and Mg are attracted to the negative electrical charges in the form of Ca^{++} and Mg^{++} ions. The negative electrical charges are referred to as exchange sites.

Those who believe in Ca – Mg balance, believe that 60% to 80% of the negative exchange sites should be occupied by Ca^{++} and 10% to 20% of the exchange sites should be occupied by Mg^{++}. This Ca^{++} and Mg^{++} is defined as exchangeable. Exchangeable Ca and Mg can be easily measured with routine laboratory procedures and it is easy to calculate ratios of exchangeable Ca^{++} to exchangeable Mg^{++}. Supposedly if the ratio of Ca^{++} and Mg^{++} is not acceptable, application of materials containing Ca and Mg can be used to correct the ratio and improve crop production.

3a. Ratio Is Not Constant in Soils

In soils in the northern Corn Belt, the ratio of Ca to Mg varies over a wide range (Table 2). This ratio also changes with cropping because uptake (lb./acre) is different for these secondary nutrients (Table 3). The data in Tables 2 and 3 come from Wisconsin. In Minnesota, the level of exchangeable Mg ranges from 50 ppm or less to more than 800 ppm.

Table 2. Ratios of exchangeable Ca to exchangeable Mg in some Wisconsin soils.

Soil Series	Ca/Mg Ratio	Soil Series	Ca/Mg Ratio
Antigo	4.0:1	Marley	4.0:1
Almena	3.2:1	Norden	8.1:1
Boone	1.0:1	Onaway	6.7:1
Dubuque	4.0:1	Ontonagon	4.0:1
Gale	4.3:1	Pella	3.9:1
Freer	3.7:1	Plainfield	6.1:1
Kewaunee	3.1:1	Plano	3.3:1
Marathon	7.7:1	Poygam	4.3:1

Source: (4)

Table 3. Change in the ratio of exchangeable Ca to exchangeable Mg with cropping in Wisconsin.

	Ca:Mg Ratio	
Soil Series	**Virgin**	**Cropped**
Plainfield sand	7.9:1	8.7:1
Boone loamy sand	1.5:1	1:1
Gale silt loam	2.6:1	4.3:1
Ontonagon silt loam	3.9:1	4.2:1

Source: (4)

4. CATION RATIOS AND CROP YIELDS

The impact of cation ratios on crop production has been the focus of research for several years. The impact of this ratio on alfalfa grown on contrasting soils in Wisconsin is shown in Table 4. The ratio was changed by adding various amounts of either Ca or Mg. The results were rather conclusive. The Ca:Mg ratio which varied over a wide range for each soil had no negative effect on alfalfa yield.

Table 4. Effect of various Ca:Mg ratios on yield of alfalfa grown on two soils in Wisconsin.

Ca:Mg Ratio	Theresa silt loam	Plainfield loamy sand
	Yield	
	- - - - - - - - - - - - ton dry matter/acre- - - - - - - - - - - - - -	
2.28	3.31	-
3.40	3.31	-
4.06	3.40	-
4.76	3.40	-
5.25	3.50	-
8.44	3.22	-
2.64	-	4.14
2.92	-	4.28
3.48	-	4.35
4.81	-	4.12
7.58	-	4.30
8.13		4.35

Source: (5)

Researchers in Ohio, working with corn and soybeans, also concluded that the Ca:Mg ratio had no effect on crop yield (Table 5). They grew corn or soybeans at several research sites. The Ca:Mg ratio was measured on soil samples collected at each site before planting. The ratios from the 5 fields having the highest yields and the 5 fields having the lowest yields are reported in Table 5. The information collected from this study leads to the obvious conclusion that the Ca:Mg ratio was not related to both corn and soybean yields.

Consider corn yields measured in 1975. The Ca:Mg ratio in 5 fields having the highest yields ranged from 5.7 to 26.8. Likewise, the ratio varied from 5.8 to 21.5 in the 5 fields that had the lowest yields.

Table 5. Ranges in the Ca:Mg in Ohio soils and relative yield of corn and soybeans.

Relative Yield	Corn (75)	Corn (76)	Soybeans (77)	Soybeans (78)
	- - - - - - - - - - - - - - - - - -Ca:Mg Ratio- - - - - - - - - - - -			
Highest Five	5.7 to 26.8	5.7 to 14.3	5.7 to 14.0	5.7 to 26.8
Lowest Five	5.8 to 21.5	5.0 to 16.1	2.3 to 16.1	6.8 to 21.5

Source: (1)

The relationship of the Ca:Mg ratio and crop production is a major theme in the debate between those marketing either dolomitic or calcitic limestone. Magnesium in dolomitic limestone is thought to have a negative impact on production because it changes the Ca:Mg ratio in soils.

Recently, this claim was tested in field trials in Olmsted County. The site selected had an initial pH of 5.6. The treatments used are listed in Table 6. The lime (either calcitic or dolomitic) was applied at a rate of supply 3500 lb. Effective Neutralizing Power per acre. Magnesium was applied as magnesium sulfate (Epsom salts). Therefore, the amount of applied

Mg increased progressively in treatments 1 through 4. The lime as well as the fertilizer needed for optimum yield was broadcast and incorporated before planting.

Table 6. Alfalfa (seeding year) and soybean yield as affected by application of either calcitic or dolomitic lime with and without additional magnesium.

Treatment #	Lime Source	Mg Applied	Crop: Alfalfa (1st cut)	Crop: Soybeans
		lb./acre	ton D.M./acre	bu./acre
1	Calcitic	0	1.42	46.0
2	Calcitic	300	1.29	46.3
3	Dolomitic	0	1.51	49.3
4	Dolomitic	300	1.47	46.3

Source:

Without the use of lime the yield was 1.24 tons dry matter per acre. Soybean yield without liming was 42.4 bu. per acre. There was a positive response to liming and this would be expected given the initial pH of 5.6.

Increasing the amount of Mg in the soil system had no negative impact on crop production. These yields lead to the conclusion that even high amounts of Mg in the soil are not detrimental. Therefore, the choice between calcitic and dolomitic lime should be based on the cost of the product rather than the perceived impact of Mg on production.

5. SUMMARY

Although differing in relative amounts found in Minnesota, the chemistry of Ca and Mg in soils and their impact on crop growth is similar. Calcium is well supplied naturally in soils and none is needed in a fertilizer program. Magnesium can be deficient when sandy soils are very acid (pH less than 5.0). As soil pH increases, the supply of available calcium and magnesium increases.

Contrary to the thinking of some, the ratio of exchangeable calcium to exchangeable magnesium has no impact on crop production. Likewise, high levels of magnesium do not decrease yield. Therefore, agronomic benefits of calcitic and dolomitic limestone are equal if equivalent rates of Effective Neutralizing Power are applied. Purchase should be dictated by cost.

REFERENCES

1. McLean, E.O., R.C. Hartwig, D.J. Eckert and G.B. Triplett. 1983. Basic cation saturation ratios as a basis for fertilizing and liming agronomic crops: II. Field Studies. Agron. J. 75:635-639

2. Rehm, G. 1994. Soil cation ratios for crop production. North Central Regional Extension Publication 533. Available at www.extension.umn.edu/distribution/cropsystems/DC6437.html (verified August 13, 2008).

3. Rehm, G., C. Rosen and M. Schmitt. 1994. Magnesium for crop production in Minnesota. University of Minnesota Extension publication FO-00725-GO. Available at www.extension.umn.edu/distribution/cropsystems/DC0725.html (verified August 13, 2008).

4. Schulte, E.E. and K.A. Kelling. 1985. Soil calcium to magnesium ratios- should you be concerned? University of Wisconsin Extension Bulletin G2986.

5. Simson, C.R., R.B. Corey and M.E. Sumner. 1979. Effect of varying Ca:Mg ratios on yield and composition of corn and alfalfa. Commun. Soil Sci. and Plant Anal. 10:153-162.