Soil calcium to magnesium ratios— Should you be concerned?

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While some sales people and scientists have claimed that there is an "ideal" soil calcium to magnesium ratio (Ca:Mg), and that Wisconsin soils contain too much magnesium for the amount of calcium present, research in Wisconsin shows this is not true. The Ca:Mg ratio seldom limits plant growth if soil pH is maintained in the good growing range. Thus, we do not recommend applying calcium materials to soils simply to increase the Ca:Mg ratios.

What is a Ca:Mg ratio?

The calcium to magnesium ratio is merely a statement of the relative proportions of available calcium and magnesium in the soil. It does not give any information about the actual levels of these elements.

For example, one soil may have exchangeable calcium and magnesium levels of 250 and 50 lb/a, respectively, while another soil may have 2,500 and 500 lb/a of exchangeable calcium and magnesium. Both have identical Ca:Mg ratios. However, in the first soil mentioned, both nutrients would be marginally low, and in the second soil, they would be present in adequate amounts.

Ca:Mg ratios also can be misleading in other ways. For example, a low Ca:Mg ratio reflects one of two possible situations: (1) a soil with low exchangeable calcium and normal magnesium, or (2) a soil with normal exchangeable calcium and high magnesium. It is impossible to distinguish between these two cases using only a ratio. On the other hand, a high Ca:Mg ratio means there is either (1) too little magnesium relative to calcium, or (2) calcium is excessive relative to magnesium.

The Ca:Mg "concept"

The idea that a proper Ca:Mg balance is necessary for good plant growth was conceived by New Jersey researchers in 1901: They recommended a total Ca:Mg ratio of about 5:4. However, soil scientists soon recognized that total element analysis is difficult and not necessarily a good measure of the amount of nutrients available to plants. Subsequently, soil scientists began searching for other methods of measuring nutrient availability.

Over the years, testing for "exchangeable" calcium and magnesium has been found to give reasonably good estimates of the amounts of these elements potentially available to plants. Exchangeable calcium and magnesium are attracted to negatively charged sites on clay and organic matter in soil where they are not easily leached from the soil but are available to plants. Currently, almost all soil testing laboratories in the United States use the test for exchangeable calcium and magnesium. However, this test may be interpreted differently depending on the research upon which it is based.

For example, the New Jersey study determined that the "ideal alfalfa soil" should have 65% of the cation exchange sites occupied by calcium, 10% by magnesium, 5% by potassium and 20% by hydrogen. However, further research has shown that these percentages can vary considerably without affecting crop yields. For example, the percent of exchangeable sites occupied by calcium can range from 55 to 75% without any yield reduction, as long as magnesium and potassium are present in adequate amounts.

Recent work in several states suggests that the optimum percent saturation of exchange sites with a given cation is not constant but depends on the cation exchange capacity of the soil. Sandy or coarse-textured soils have a low cation exchange capacity and require a higher percent potassium saturation. On the other hand, medium- or fine-textured soils have a high cation exchange capacity and do not require as high a percent of potassium saturation.

The mineralogy of the soil is also an important factor in determining optimum percent saturation of exchange sites with a given cation. Some soils, such as the reddish soils of eastern and northern Wisconsin, can release significant amounts of nonexchangeable potassium. The optimum percent potassium saturation is lower for these soils than soils having little nonexchangeable potassium.

Because of these differences in the cation exchange capacity of soils and soil mineralogy, the concepts of cation ratio and percent base saturation cannot be applied to all soils. In addition, research on other states' soils does not necessarily apply to Wisconsin soils.

According to an early survey, calcium and magnesium levels in Wisconsin soils vary considerably. Calcium content ranged from 50 lb exchangeable calcium/a (in Boone loamy sand (Monroe County) with a Ca:Mg ratio of 1:1 to 18,000 lb/a in a Westerville silt loam (Richland County) with a ratio of 5.1:1.

Exchangeable magnesium ranged from 26 lb/a in an Ottawa loamy sand (Juneau County) with a Ca:Mg ratio of 4.6:1 to 8,340 lb/a magnesium in a Pella silt loam (Kenosha County) with a ratio of 0.3:1. This latter sample was the only sample of 668 taken in Wisconsin where the Ca:Mg ratio was less than 1:1. At other sites, Pella silt loam had Ca:Mg ratios between 3:1 and 4:1.

Table 1 shows that most of the common soil types in the state have Ca:Mg ratios that range from 1:1 to 8:1.

Table 1. Ratio of exchangeable calcium to exchangeable magnesium in some Wisconsin soils.[a]

Soil	Ca:Mg ratio	Soil	Ca:Mg ratio
Antigo	4.0:1	Norden	8.1:1
Almena	3.2:1	Onaway	6.7:1
Boone	1.0:1	Ontonagon	4.0:1
Dubuque	4.0:1	Pella	3.9:1
Fayette	6.3:1	Plainfield	6.1:1
Gale	4.3:1	Plano	3.3:1
Freer	3.7:1	Poygan	4.3:1
Kewaunee	3.1:1	Withee	3.5:1
Marathon	7.7:1		
Morley	4.0:1		

[a]*Ratio expressed on pounds per acre exchangeable basis. These may be converted to an equivalent weight basis by multiplying by 0.61.*

More recently, test results from Wisconsin soil testing laboratories (January 1977 to December 1981) found the average levels of exchangeable calcium and magnesium to be 2,830 and 745 lb/a, respectively. This gives an average Ca:Mg ratio of 3.8:1. Less than 1% of the 34,755 samples analyzed for calcium had less than 250 lb Ca/a, and 4.8% contained more than 6,000 lb/a. Only 0.2% of these samples contained less than 25 lb Mg/a and 5.8% had more than 1,600 lb/a.

Wisconsin research

Some experimental work in Wisconsin varied the Ca:Mg ratio by adding gypsum ($CaSO_4$) and/or Epsom salts ($MgSO_4$) to two soils, Theresa silt loam (pH 6.8) and Plainfield loamy sand (pH 6.8). Phosphorus, potassium and sulfur were maintained at optimal levels throughout the experiment. Corn and alfalfa were grown as indicator crops.

Table 2 shows the changes in alfalfa yield resulting from varying the Ca: Mg ratio. The results for corn, which yielded 100 and 140 bu/a in 1974 and 1975, respectively, are essentially the same as those for alfalfa.

According to this study, varying the Ca:Mg ratio from slightly above 2 to more than 8 did not significantly affect yield on either soil. Adding calcium and magnesium to the soil did change the percent calcium saturation of the exchange sites from anywhere between 32 to 68% and the magnesium saturation from 35 to 12% (Table 2). In general, the Ca:Mg ratio in the plant increased with increasing the Ca:Mg ratio in the soil, although much more slowly and not always consistently. This demonstrates the selective ability of the plant in taking up nutrients. At all sites and for all crops, the calcium and magnesium levels in the soil and plants were above the deficient ranges. See Extension publications *Soil and Applied Calcium* (A2523) and *Soil and Applied Magnesium* (A2524).

Thus, if adequate levels of calcium and magnesium are present in the soil, variations in the Ca:Mg ratio between 2 and 8 have no effect on yield, and varying the calcium saturation percentage from 32% to 68% and magnesium from 35% to 12% also do not influence yield.

These results are not surprising considering the way that calcium and magnesium are supplied to plants. These nutrients are moved to the roots in the water which the plant uses. A corn crop transpires between 250,000 and 400,000 gallons/a water during the growing season. By multiplying the amount of water used by the concentration of calcium and magnesium in the soil solution, you get an estimate of the amount of calcium and magnesium supplied to the root surface. For most Wisconsin soils, about 250 to 400 lb/a calcium and 100 to 160 lb/a magnesium are supplied to the root surface through transpired water.

These values are much greater than the 26 to 40 lb/a calcium and 15 to 30 lb/a magnesium taken up by a 150 bu/a corn crop. Thus, the amounts of these nutrients taken up are determined by the selectivity of the roots. The remainder accumulates in the immediate vicinity of the roots.

Therefore, it is doubtful that the supply of calcium and magnesium to the root surfaces would ever be limiting under Wisconsin conditions where soil pH is maintained in good growing range. The Ca:Mg ratio seldom will be the dominant factor determining calcium and magnesium uptake by plants. This was shown by the small variations in the tissue Ca:Mg ratio when the soil Ca:Mg ratio was varied (table 2).

Table 2. Effect of varying Ca:Mg ratios on yield and calcium and magnesium levels in alfalfa.

—— Ca:Mg ratio ——		% exchange saturation		
Soil[a]	**Plant**	**Ca**	**Mg**	**Yield**[b] **(t/a)**
Theresa silt loam				
2.28[c]	2.15	34	35	3.31
3.40	2.36	45	22	3.31
4.06	2.53	46	19	3.40
4.76	2.87	49	17	3.40
5.25	2.97	52	16	3.50
8.44	3.29	62	12	3.22
Plainfield loamy sand				
2.64[d]	2.48	32	20	4.14
2.92	2.70	35	20	4.28
3.48	3.32	38	18	4.35
4.81	3.35	43	15	4.12
7.58	4.14	65	13	4.30
8.13	3.64	68	15	4.35

[a] *Variations in exchangeable calcium and magnesium were achieved by adding up to 7,700 lb/a gypsum and 15,400 lb/a Epsom salt.*

[b] *No statistically significant yield differences were obtained.*

[c] *Exchangeable calcium and magnesium ranged from 1,640 to 3,040 lb/a and 380 to 744 lb/a, respectively. Expressed on a lb/a exchangeable basis.*

[d] *Exchangeable calcium and magnesium ranged from 950 to 2,050 lb/a and 240 to 390, respectively. Expressed on a lb/a exchangeable basis.*

Data selected from 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. in Soil Sci. and Plant Anal. 10:153–162.

Another question often asked about Ca:Mg ratios is the concern that cropping may lead to high or even harmful or toxic levels of magnesium in soil. In Wisconsin research, the Ca:Mg ratio remained the same or increased after cropping on all tested soils except the Boone loamy sand (table 3). In the case of the Boone sand, the ratio decreased as a result of a lowering of the exchangeable calcium rather than an increase in exchangeable magnesium (from 75/50 to 50/50 lb; or a ratio change from 1.5:1 to 1:1).

Potential problems

Recently, paper mill lime sludge (mainly $CaCO_3$) has become available as a calcitic liming material. Using this material as a source of calcium to bring Ca:Mg ratios into "balance" on soils not requiring lime can result in severe nutrient deficiencies. Because of the presence of hydrated lime, $Ca(OH)_2$, in paper mill lime sludge, soil pH values can quickly reach 9.0 when excessive quantities are applied. Under such conditions, trace elements as well as magnesium can become deficient.

Gypsum ($CaSO_4$) and calcitic limestone ($CaCO_3$) often may be recommended to balance Ca:Mg ratios. However, continued application of gypsum or calcitic lime results in wide Ca:Mg ratios. This may give rise to magnesium-deficient forage which causes grass tetany in grazing animals. Once this stage is reached, it becomes very expensive to add sufficient magnesium to remedy the situation.

Table 3. Change in the ratio of exchangeable calcium to exchangeable magnesium with cropping.

	Ca:Mg ratio	
Soil	**Uncropped**	**Cropped**
Plainfield sand	7.9:1 a (850/108)	8.7:1 (590/68)
Boone loamy sand	1.5:1 (75/50)	1:1 (50/50)
Gale silt loam	2.6:1 (540/206)	4.3:1 (2,040/472)
Ontonagon silt loam	3.9:1 (1,930/490)	4.2:1 (2,660/634)

[a] *The numbers in parentheses are the actual pounds of exchangeable calcium/exchangeable magnesium.*

Recommendations

- Calcium deficiencies in Wisconsin are rare in soils above pH 6.0. However, if a crop requiring a low pH is being grown and liming is not recommended, gypsum can supply calcium to the crop.
- If liming is required, a dolomitic or calcitic liming material will supply sufficient calcium to maintain crop growth. Dolomitic lime sources have the added benefit of increasing available magnesium.
- Choose the most economical liming material when liming is required. Do not apply gypsum or calcitic limestone to Wisconsin soils simply to increase soil Ca:Mg ratios.
- If you choose a liming material low in magnesium, be careful to avoid magnesium deficiencies. High calcium applications alone can decrease soil and plant magnesium levels. If the soil is acid and originally has a low magnesium content, adding a calcitic (low Mg) liming material or high rates of gypsum could induce a magnesium deficiency.

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