What happens in the soil when you apply aglime or gypsum?

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① Apply aglime or gypsum.

Choose rates based on soil tests, your own experience, and/or work with a consultant; see other side for some more considerations.

② Material dissolves (or not).

Aglime and gypsum cannot affect your soil or plants until they dissolve in water. This can happen slowly, requiring months or even years. The rates at which aglime and gypsum dissolve are determined by many factors, including:

- **Rainfall** - Without water, gypsum and aglime will not dissolve and will have no affect on soil or plants.
- **Amount applied** - If you keep adding sugar to a cup of water, you'll reach a point where added sugar will just sit on the bottom rather than dissolving. Gypsum is much more soluble than aglime, but both materials can behave the same way, and very heavy applications may just sit without affecting either soil or plants, even if there's a lot of rain.
- **Particle size** - Finely ground materials are more expensive but have more surface area and dissolve faster. This is not usually an issue for gypsum, which is naturally fine, but is important for aglime.
- **Tillage** - If at all possible, aglime and gypsum should be mixed into the soil by tillage shortly after application. This will greatly increase the rate at which they dissolve. Unincorporated materials dissolve slowly and may be lost to wind erosion before they can dissolve.
- **pH (acidity) of your soil at application** - Aglime is more soluble in an acid soil than it is in a neutral or basic soil.

③ Aglime raises pH...

Liming materials include calcium carbonate ($Ca(CO_3)$, which is crushed limestone) and calcium magnesium carbonate ($CaMg(CO_3)_2$, which is known as dolomitic limestone or dolomite). When these materials dissolve in water, the positively charged calcium (Ca^{2+}) and magnesium (Mg^{2+}, if present) can interact with negatively charged clay and organic matter in the soil through which the water is moving, replacing some positively charged ions, including protons (H^+), potassium (K^+), sodium (Na^+) and/or any calcium or magnesium that may already be present.

If protons are displaced, the carbonate parts of the liming materials (CO_3^-) can then react with the protons (H^+) to make water and carbon dioxide (CO_2), a gas that then leaves the soil. Chemists write this as:

$$CO_3^- + 2H^+ \rightarrow CO_2 + H_2O$$

Note that it is the carbonate and not the calcium (or magnesium) that actually removes protons and raises soil pH.

④ ...while gypsum does not.

Gypsum ($Ca(SO_4) \cdot 2H_2O$) is more soluble than aglime, but contains no carbonate, so it does not act to raise soil pH.

However, like the calcium in aglime, the calcium (Ca^{2+}) in gypsum can interact with negatively charged clay and organic matter in the soil, replacing some of the positively charged ions that are already present.

The sulfate (SO_4^-) in gypsum temporarily raises soil sulfur levels, but because most soils have little ability to bind negatively charged ions, almost all of the sulfate just washes out. Unlike elemental sulfur, sulfate does *not* lower soil pH.

Because gypsum does not raise soil pH and is not mined in Wisconsin, it is rarely used here except by those who are trying to increase levels of soil calcium.

⑤ In the end, much of what you add is lost.

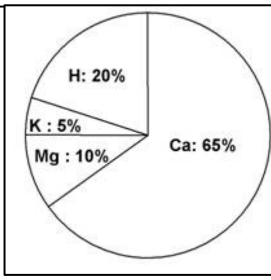
Whether you apply aglime or gypsum, much of the material ends up getting washed into ground and surface water without doing anything to your soil.

Why add calcium-containing minerals to your soil?

pH correction - First, since use of nitrogen fertilizers (*including nitrogen from legumes!*) acidifies your soil, it's a good idea to apply aglime regularly to push soil pH back up toward the range (close to 6.8) that's favorable to crop growth. As discussed on the other side of this sheet, gypsum does *not* raise soil pH and should not be purchased for this purpose.

Changing levels of cations - Some farmers are also interested in changing the relative amounts of the cations (positively charged ions) calcium, magnesium, and potassium attached to the negatively charged clay and organic matter in their soils. A substantial body of research suggests that changing these cation ratios has no direct effect on plants, but we are now in the third year of a trial to see if changing these ratios in an organic cropping system affects plants' ability to defend themselves against feeding by insects. We can't yet tell you whether or not calcium additions help with insect pest problems, but we can tell you a little bit about our efforts to change our soil, which has turned out to be more complicated than we thought.

Is changing soil cation ratios possible on a farm scale?



The pie chart at right shows the proportions of the positively charged ions, or cations, that are sometimes considered to make soil best for plant growth. Though early soils researchers referred to these proportions as the "ideal soil," some proponents of the ratio concept feel calcium levels should be even higher, perhaps filling as much as 70% or even 80% of the potential sites on clay and organic matter.

At the start of this experiment in 2006, calcium (Ca) filled an average of 59% of the cation exchange capacity of the soil (a silt loam) in our experimental plots. Magnesium (Mg) filled an average of 34%, and potassium (K) filled an average of just under 4%. To make our soil more like the "ideal" soil, it seemed we needed to replace various cations, and particularly magnesium, with calcium.

In an attempt to do this, half of our plots have since received aglime once (1.5 tons/acre) and gypsum twice (1.25 tons/acre and 1.33 tons/acre). As a result, in fall of 2010, calcium made up approximately 71% of the exchangeable cations in the treated plots, magnesium had decreased to about 25%, and potassium levels were just under 3%. While these changes have not yet resulted in significant differences in the numbers of pests or beneficial insects between calcium-treated and untreated plots, we expect that the soil in our plots will continue to change over time in ways that might affect plants and, in turn, insect pests and their natural enemies. As a result, we are continuing to collect insect data during each field season, and may well apply more gypsum to the appropriate plots to further increase levels of exchangeable calcium relative to other cations.

While we have achieved a more significant change in calcium levels than has been seen in most other field trials (including a recent three-year study by the Practical Farmers of Iowa and Iowa State University), it is perhaps worth noting that, theoretically, just 1 ton per acre of gypsum should have increased our soils' calcium levels from about 60% to 70%, while 3.3 tons should get them to 85% calcium. However, these calculations rely on some incorrect assumptions. Most importantly, they assume that *all* of the calcium added replaces magnesium, potassium, or protons (Mg, K, and H in the pie chart above). Unfortunately, most of the calcium (and the associated sulfate) probably washes out of the soil without exchanging with anything at all. Much of the calcium that *doesn't* wash out just exchanges with the most abundant cation already present, calcium, and the displaced calcium then washes out. Only a small proportion of the added calcium replaces magnesium, potassium, or protons (which may then also wash out).

In April 2010 we finished a series of greenhouse studies involving raising insects on plants grown in pots of specially modified soils. These soils, which we altered in the lab with a process developed by other researchers, have particular ratios of calcium and magnesium that are difficult to achieve in the field. We thought that using these soils in the controlled conditions of the greenhouse might reveal soil-plant-insect interactions that are obscured in the field by natural year-to-year and plot-to-plot variations in soils, weather, pest density, and other factors. As it turned out, soybean aphids and beet armyworm larvae responded the same way to plants grown in soils containing all of the cation ratios we created.

Farm Advisory Panel and Arlington Research Station Staff

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