Lime Recommendations for Field Crops

For optimum production of field crops in New York, it is important to test fields for soil pH at least once every 3 years and to add lime if the pH is below the optimum range for the crops in the rotation. However, a pH measure only tells us if lime is needed, not how much is needed. In this fact sheet, we will explain how lime recommendations are calculated.

What Happens When We Lime

Soil particles are negatively charged and have many different sites where positively charged particles can attach. These sites are referred to as cation exchange sites because they attach positively charged cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+}), hydrogen (H^{+}) and aluminum (Al^{3+}). Cations can be classifed as basic (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) or acid (such as H^{+} and Al^{3+}). If released into the soil solution, basic cations will raise the pH. Acid cations will lower pH when released into the soil solution. In order to raise the soil pH, the acid cations have to be removed from the cation exchange sites and neutralized. When a liming material such as calcium carbonate is added to the soil, the calcium replaces the H^{+} and/or Al^{3+} on the exchange sites and the carbonate acts to neutralize the H^{+} and Al^{3+}.

Different Forms of Soil Acidity

The amount of lime to be added depends on soil texture and organic matter content which affect the soil's capacity to buffer changes in pH. A soil with a large buffer capacity (more clay size particles and/or organic matter) will need more lime to neutralize acidity than a soil with a small buffer capacity. The buffer capacity of the soil is determined by its total acidity which is the sum of three different forms of soil acidity:

1. Active acidity (pH).
2. Salt-replaceable acidity.
3. Residual acidity.

Active acidity reflects the hydrogen (H^{+}) ion activity in the soil solution and is measured as the soil's pH. To neutralize only the active acidity, very little calcium carbonate would be needed. However, such a change would be very short-lived because of the existence of salt-replaceable and residual acidity. Salt-replaceable acidity and residual acidity can be described as the soil's capacity to resist change in the soil solution pH. Salt-replaceable acidity is the H^{+} and Al^{3+} activity in solution when shaken with a neutral (pH 7) salt solution. The amount of lime needed to neutralize this acidity is much greater than what would be needed to neutralize the active acidity. Residual activity is associated H^{+} and Al^{3+} ions that are bound non-exchangeably to organic matter and clays. This acidity needs the greatest amounts of lime to be neutralized. Because the active acidity (pH) is only a fraction of the total potential acidity in the soil, a pH measurement can only tell you whether or not lime addition is needed, not how much is needed. We need a measure of the soil's "buffer capacity" to determine the amount of lime needed to increase the pH.

Measuring Exchangeable Acidity

In the Cornell Nutrient Analysis Laboratory, the buffer capacity of a soil is determined by its amount of exchangeable acidity (EA). Exchangeable acidity is the total potential acidity present in the soil between its actual pH and pH 8.2.

Determining Lime Recommendations

Lime recommendations depend on:

1. Current and desired pH.
2. Exchangeable acidity.
3. Base saturation of the soil at the current and at the desired pH.
4. Tillage depth.

Base saturation is the amount of basic cations divided by the total cation exchange capacity (total number of cation exchange sites). So, if the base saturation is 0.75, 75% of the cation exchange capacity is occupied by Ca^{2+}, Mg^{2+}, K^{+} and/or Na^{+} while 25% is exchangeable acidity. For soils with a pH of 6.0 or lower, the lime recommendation is determined by the exchangeable acidity, base saturation at the original pH and at the desired pH, and the tillage depth (TD, inches):

$$\text{Lime Req.} = EA*0.5*\frac{(BS_{desired}-BS_{original})}{(1-BS_{orginal})}*(TD/6)$$

Where the pH of the soil is 6.1 or higher, the exchangeable acidity is negligible but there is still residual acidity. For these soils, the exchangeable acidity measurement needs to be replaced by estimated cation exchange capacity (CEC). The base saturation at the current pH and the desired pH can be determined from Table 1. Estimated CEC for different soils are given in Table 2.

Table 1: Base saturation as affected by soil pH.

pH	Base Saturation (fraction)	pH	Base Saturation (fraction)
<4.5	0.00001	6.3	0.675
4.5	0.021	6.4	0.695
4.6	0.035	6.5	0.710
4.7	0.050	6.6	0.730
4.8	0.073	6.7	0.740
4.9	0.102	6.8	0.755
5.0	0.135	6.9	0.770
5.1	0.171	7.0	0.795
5.2	0.228	7.1	0.812
5.3	0.320	7.2	0.830
5.4	0.420	7.3	0.847
5.5	0.480	7.4	0.863
5.6	0.515	7.5	0.880
5.7	0.540	7.6	0.900
5.8	0.570	7.7	0.925
5.9	0.600	7.8	0.950
6.0	0.620	7.9	0.975
6.1	0.635	>7.9	1.000
6.2	0.655		

Table 2: Cation exchange capacity (CEC) is determined by the soil management group (SMG).

SMG	General Description	CEC $cmol_c/kg$
1	Fine-textured soils developed from clayey lake sediments and medium- to fine-textured soils developed from lake sediments.	25
2	Medium- to fine-textured soils developed from calcareous glacial till, medium- to moderately fine-textured soils developed from slightly calcareous glacial till mixed with shale, and medium-textured soils developed in recent alluvium.	20
3	Moderately course textured soil developed from glacial outwash or recent alluvium and medium textured acid soil developed on glacial till.	18
4	Course- to medium-textured soils formed from glacial till or glacial outwash.	16
5	Course- to very course-textured soils formed from gravelly or sandy glacial outwash or glacial lake beach ridges or deltas.	12
6	Organic or muck soils with more than 80% organic matter.	12

Lime Recommendations for No-Till

The lime equation shows that the lime recommendation will increase if the tillage depth is greater than 6 inches. In a no-till system soil is not mixed and the pH values of two soil layers (0-1 and 0-6 inches) need to be considered. Depending on the results, three management options are possible:

- If the pH of the surface 0-1 inch is low, but the pH of the 0-6 inch zone is adequate, add 1 to 1½ tons of lime per acre to raise the pH of the soil surface.
- If both layers are strongly acidic do not use no-tillage methods for the establishment of legumes until lime has been given 6 to 9 months to react with the soil.
- If the surface (0-1 inch depth) pH is adequate, but the 0-6 inch soil zone has a low pH, legumes might be no-till seeded with a slightly lower overall pH or without waiting as long for the lime to react as when both zones have a low soil pH.

In Summary

Soil pH will tell us if lime is needed. Lime recommendations will vary from one field to another depending on current pH and desired pH, the capacity of the soil to buffer changes in pH (expressed as exchangeable acidity of CEC), and tillage depth. The Cornell Nutrient Analyses Laboratory (CNAL) will generate lime recommendations based on soil analyses and crop rotations and report them on a 100% Effective Neutralizing Value (ENV) basis. To determine actual application rates, recommended lime rates need to be divided by the ENV of the liming material (see Agronomy Fact Sheet #7 for details on liming materials).

Additional Resources

- Agronomy Fact Sheet #1 (Soil sampling for field crops); #5 (Soil pH); #7 (Liming materials). nmsp.css.cornell.edu/publications/factsheets.asp.

For more information

Cornell University Cooperative Extension

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