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Soil Acidity: What It Is, How It Is Measured, Why It Is Important

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Figure 1. Measurement of soil pH (photo courtesy UK Regulatory Services website).

Soil chemical health is strongly related to soil acidity. This acidity consists of acidic cations, hydrogen (H^+), aluminum (Al^{3+}), and in some soils, manganese (Mn^{2+}). The acid cations are neutralized by basic anions, carbonate (CO_3^{2-}), hydroxyl (OH^-), and oxide (O^{2-}) provided by materials such as agricultural, hydrated/slaked, and quick/burnt limes, respectively. Lime application rates are based on the amount of acidity measured in your soil sample.

One important measure of soil acidity status is soil pH, which is measured by electrodes placed in suspensions (Figure 1) of soil in water or a salt (calcium chloride, CaCl2, or potassium chloride, KCl) solution. The pH measured in these suspensions is related to the hydrogen ion (H^+) activity of the soil-water system. Chemically, $pH = -\log(H^+)$. This means that for a pH drop of 1 unit (e.g., from pH 6 to pH 5), there will be a tenfold increase in H^+ activity in the soil solution. If pH rises by 1 unit, only one-tenth as much acidity will be present in the solution.

A salt solution is more appropriate for soil pH measurement when drought results in fertilizer salt residues in fall soil samples. Summer droughts are not uniform, statewide, and resulting fertilizer salt carryover is both significant and variable. Carryover salt causes lower and more variable pH values measured in suspensions of soil and water. The University of Kentucky (UK) soil test lab determines pH in a suspension of soil and KCl solution that "swamps" salt carryover differences among samples. The soil-KCl pH values are converted to and reported as soil-water pH values using the equation: soil-water pH = (0.91 x soil-KCl pH) + 1.34. Soil-water pH is commonly referred to as 'soil pH'.

Soil pH values less than 7.0 are acidic and those greater than 7.0 are alkaline. These pH measurements only determine the active acidity in the soil solution bathing plant roots. The "active" fraction of total soil acidity is extremely small. Less than a half-pound of calcitic lime per acre would neutralize the active acidity contained in the soil solution of 8 inches of pH 5 silt loam topsoil at field moisture.

A much larger portion of total soil acidity, termed reserve (potential) acidity, resides on the surface of soil clay and organic matter particles. This particle surface acidity is in equilibrium with the solution active acidity, and the greater the clay or organic matter content, the greater the soil's ability to resist solution pH changes by either releasing or adsorbing H^+. This resistance is the soil's buffer capacity. Soils with different textures (sand vs. silt vs. clay) can have the same level of active acidity, the same pH in soil plus water/simple salt suspensions. But these soils will have very different quantities of reserve acidity that needs to be neutralized. This causes soil test labs to use another measurement, buffer pH, to measure reserve acidity and help determine soil lime requirement. When an acid soil is suspended in the buffer solution, the buffer reacts with reserve acidity, causing the measured soil-buffer suspension pH to be lower than that of the buffer by itself. The UK soil test lab uses the Sikora-2 buffer, which has an initial pH of 7.5. The lower the soil buffer pH, the greater the soil's reserve acidity and the greater the amount of lime needed to neutralize that acidity – the lime requirement.

Understanding the soil's acidity status is important. Soil pH can serve as a general indicator of soil health/nutrient availability, much like body temperature indicates general animal health. Typical Kentucky soil pH values fall between 4.5 and 7.5. Soil pH values from 6.4 to 7.0 promote nodulation of legumes and the biological nitrogen fixation that sustains these crops. Low pH can slow biological mineralization of organic matter and crop residues, reducing the release of organic nitrogen, phosphorus, sulfur, and boron.

As soil acidity rises, soil pH falls and potentially toxic elements like manganese and aluminum become more soluble and available for plant uptake. Acid soils reduce the solubility and uptake of other nutrients, especially phosphorus and molybdenum. Surface soil acidity can reduce the effectiveness of triazine herbicides. Alkaline soils with excessively high soil pH values can also exhibit potential for nutrient stress. Deficiencies of boron, manganese, phosphorus, and zinc have been observed on high pH soils in Kentucky. Copper and iron deficiencies have been reported in other states. Over-liming, whether due to excessive application rates or improper spreader operation, should be avoided.

Different crops have different soil pH needs (see AGR-1: "Lime and Nutrient Recommendations, 2020-2021" at http://www2.ca.uky.edu/agcomm/pubs/agr/agr1/agr1.pdf). Blueberries, potato, and azaleas grow well at lower soil pH values. For tobacco, the target pH is 6.6 and UK recommends lime when the soil pH falls below 6.4. Alfalfa needs an even greater pH of 6.8, with lime recommended if soil pH is less than 6.6. The greatest Kentucky soil acreage is under corn, soybean, grain sorghum, canola, small grain (barley, oats, rye, wheat, and triticale) and forage (pasture and hay), with a target pH of 6.4. Lime is recommended when soil pH falls below 6.2 (see Table 1).

Table 1. Rate of 100% effective (RNV = 100) limestone, in tons per acre, needed to raise soil pH to 6.4 as related to soil sample water and buffer pH values.

Water pH of Sample	Buffer pH of Sample								If Buffer pH is Unknown
	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	
4.5	4.50	4.25	4.00	3.50	3.00	2.50	2.00	1.50	2.75
4.7	4.50	4.25	4.00	3.50	3.00	2.50	2.00	1.50	2.75
4.9	4.50	4.25	3.75	3.25	2.75	2.25	1.75	1.25	2.75
5.1	4.50	4.25	3.75	3.25	2.75	2.25	1.75	1.25	2.75
5.3	4.50	4.25	3.75	3.25	2.50	2.00	1.50	1.00	2.25
5.5	4.50	4.25	3.50	3.00	2.50	2.00	1.50	1.00	2.00
5.7	4.50	4.00	3.50	2.75	2.25	1.75	1.25	1.00	1.75
5.9		4.00	3.25	2.50	2.00	1.50	1.00	0.75	1.25
6.1			2.75	2.00	1.50	1.00	0.75	0.50	1.00

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