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The value of lime in turfgrass management

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Spring is fast approaching and the workload for the turf manager is already increasing. By the time winter damage has been fully assessed and corrective measures taken, there is the risk of overlooking a very simple yet basic part of turf culture: determining the need for soil pH adjustment.

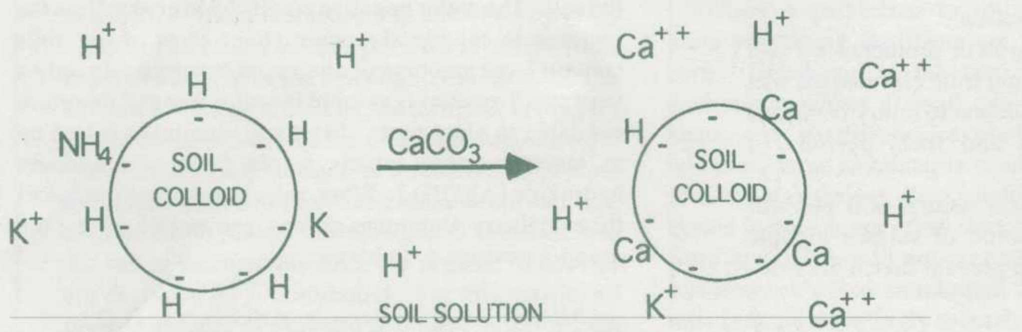
Soil pH and grass growth

For most areas east of the Mississippi, this involves adding lime to raise soil pH to between 6.0 and 6.5. Most turfgrasses grow best within that pH range. While some bentgrasses and fine-leafed fescues will tolerate lower pHs, even they often respond favorably to lime applications.

One problem with pH adjustments is that the grass rarely tells you that the soil is becoming too acid. Any turf decline due, in part, to acid soil conditions is so gradual that even the most attentive manager will rarely see it happening. Lime application is one management practice that is best scheduled by the calendar. Of course an annual soil test will indicate if your soil is becoming too acid and it should raise the red flag that corrective action is needed. Why is soil pH important? You probably know turf managers who rarely use lime and maintain excellent quality turf. During times when budgets are tight, isn't lime application one expense that can safely be delayed?

I would answer this last question in the

Calcium exchange for H^+ on soil colloids



Calcium ions from calcium carbonate exchanging for hydrogen on soil colloids of an acid soil. Hydrogen released from colloids into solution are neutralized by hydroxides which are produced when calcium carbonate dissolves in soil water.

Figure provided by Dr. Richard J. Hull, University of Rhode Island

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negative. While soil pH adjustment can be delayed without causing marked injury to your grass, lime application remains one of the most cost-effective practices in turf management.

Advantages of raising pH

Reducing soil acidity by applying lime is beneficial in ways that are not obviously linked with soil pH.

- Increasing soil pH by adding lime increases the availability of several plant nutrients and makes fertilizer applications more effective.
- Increasing soil pH reduces the plant availability of toxic aluminum and manganese. Aluminum stunts root growth and makes grasses less able to recover nutrients and water.
- Calcium added as lime is a plant nutrient that increases the efficiency with which grass roots can absorb other nutrients.
- Increasing soil pH favors microorganisms which are responsible for turning over organic matter thereby making residual nitrogen more available to grass roots and probably suppressing the growth of disease causing organisms.
- By stimulating microbial activity and favoring vigorous root growth, reduced soil acidity will minimize the opportunities for nitrate leaching into ground water.
- Increased biological activity of the soil promoted by higher pH will contribute to improved soil structure with increased air and water penetration.
- Increased root growth promoted by soil conditions resulting from elevated pH will make grass less subject to injury from root feeding insects and from periods of drought.
- Maintaining a near neutral soil pH will speed decomposition of surface organic residues and help prevent thatch accumulation.

Other advantages attributable to soil pH adjustment through the application of lime could be stated, but this list gives you some idea of the broad range of benefits that have been linked to the use of lime. Given the low cost of ground limestone and its comparative ease of application, is there any surprise that the benefits derived from its use make lime one of the most cost effective materials available to the turf manager? You might be suspicious that these claims for lime use are a bit exaggerated so let us consider the scientific basis for them.

Soil pH and plant growth

To begin, it might be useful to explain what soil acidity and pH are. Acidity simply indicates the relative concentration of hydrogen ions (H^+) in a solution. The more H^+ present in a solution, the more acid it will be. Mildly acid substances have a sour taste due to the presence of H^+. The concentration of H^+ in a solution is indicated by its pH which is the negative logarithm of the H^+ concentration expressed in moles per liter of solution. The H^+ concentration in most solutions is a very small number, e.g. a neutral solution contains 0.000,000,1 moles H^+ per liter of solution. Such small numbers are cumbersome to handle so they are often expressed as an exponential where 0.000,000,1 = 1.0×10^{-7} or as a logarithm = -7.0. To avoid the negative values, it is conventional to express H^+ concentrations as a negative logarithm so -7.0 becomes 7.0. For those not familiar with logarithms, this can become confusing because you might think a pH of 7.0 should be more acid than one of 5.0 when the reverse is true. The table on page 5 shows the relationship between pH units and H^+ concentration of solutions.

Acidity and interaction with the soil

Soil acidity is not in itself harmful to plants and does not inhibit root growth. Many plants will grow happily in a nutrient solution when its pH is between 4 and 5. Acidity is a problem primarily due to its interaction with the soil. The major negative condition in acid soils is the increase in soluble aluminum (Al). Most of our soils contain large amounts of aluminum but normally only a very small amount is soluble in soil water and therefore available to plant roots. Most soil aluminum is tied up as mineral matter largely in the form of aluminum hydroxide [$Al(OH)_3$]. When soils become acid, some of these hydroxy aluminum groups lose an OH^- giving the group a positive (+) charge.

$$Al(OH)_3 + H^+ \longrightarrow Al(OH)_2^+ + H_2O$$

Such positively charged groups are much more soluble in water than the uncharged $Al(OH)_3$. When the soil pH drops below 5.0, some mineral aluminum loses all of its hydroxides and goes into solution as a free triple charged aluminum ion (Al^{+3}). Such charged aluminum groups are dissolved in the soil solution and can be absorbed by

-continued on page 4

plant roots. The $Al(OH)_2^+$ form is absorbed most because triple charged ions do not cross root cell membranes easily. When a soil of pH 4.5 was extracted with a KCl solution, 4.33 meq of Al were removed from each 100 grams of soil. The same soil at pH 5.5 lost only 0.37 meq of Al/100 grams of soil. Consequently, making the soil less acid dramatically reduces the amount of aluminum available to turfgrasses.

It is not understood exactly how aluminum inhibits root growth but it clearly does. Plants growing in a nutrient solution containing more than 10 ppm of soluble Al produced stunted brown roots similar to those of plants growing in an acid soil. When soils become acid, other metallic elements including manganese and iron can also be made soluble and will contribute to plant toxicity. Iron and manganese are essential nutrients for plants but at the high concentrations present in acid soils, they too will cause injury to root cells and inhibit growth. In most cases, however, soluble aluminum is responsible for poor plant growth in acid soils.

While some metals (Al, Mn, Fe, Zn) become more available to plants in acid soils, others become less available. As indicated above, nitrogen availability depends on organic matter decomposition which is depressed in acid soils. Therefore, nitrogen is more likely to be inadequate when soil pH is low. Nutrients like phosphorus, molybdenum and to a lesser extent sulfur become bound into mineral structures when soils are acid and are most available to plants when soil pH is between 6 and 7. For reasons which will be explained later, potassium, calcium, magnesium and copper are readily leached from very acid soils and are best retained in a plant available form in soils of pH 6 to 7. Clearly, soil pH has a dramatic influence on the soil's ability to deliver nutrients to plant roots in a form that can be used.

Acid soil conditions not only inhibit root growth, they also depress the growth and activity of many microorganisms. Thus an acid soil may have a somewhat unique microflora, often dominated by fungi, which normally will not decompose organic residues as rapidly as the bacteria and fungi present in less acid soils. Many soil microorganisms have a distinct pH optimum for their growth which is not related to toxic metals in soil solution. Many nitrogen transforming reactions which are carried out by soil bacteria, e.g. nitrification and nitrogen fixation, are severely restricted in acid soils. This reduced biological activity caused by acid conditions creates a soil environment which does not permit rapid turnover of plant nutrients either from plant residues or organic fertilizers and makes the soil generally less fertile and suitable for plant growth.

How does lime raise soil pH?

While there are several liming materials, the least expensive and most widely used on turf is ground limestone. Limestone is composed mostly of calcium carbonate ($CaCO_3$) which is a natural mineral mined throughout the world. It is ground to a fine powder so that all will pass a 10 mesh screen and about 20% will pass a 60-100 mesh screen. The finer the grind, the more rapidly limestone will raise soil pH. When added to an acid soil, ground limestone reacts with soil water and releases into solution free calcium ions (Ca^{++}), bicarbonate ions (HCO_3^-) and hydroxide ions (OH^-).

$$CaCO_3 + H_2O \longrightarrow Ca^{++} + HCO_3^- + OH^-$$

The OH^- then reacts with H^+ in the soil solution to form water.

$$OH^- + H^+ \longrightarrow H_2O$$

If the soil is sufficiently acid, the HCO_3^- will form another OH^- which will react with another H^+ to produce H_2O and CO_2. The CO_2 is a gas and is lost to the atmosphere.

$$HCO_3^- + H^+ \longrightarrow CO_2 + H_2O$$

Thus, for every $CaCO_3$ that reacts completely with the soil solution, two H^+s are neutralized to water.

That is how limestone removes H^+ from the soil solution but it also does another important job. The Ca^{++} released into the soil solution from limestone displaces H^+s that are attracted to fixed negative (-) charges on the solid particles of the soil. The Ca^{++} replaces H^+s on the fixed negative charges and the H^+s (now in solution) are neutralized by other $CaCO_3$ molecules from limestone. Thus, not only are H^+s in solution neutralized by limestone but also those H^+s bound to negative exchange sites on the fine solid particles of the soil. Most of the acidity in a soil is the result of H^+s bound to exchange sites and because limestone neutralizes them as well as those in solution, it is very effective in raising soil pH (lowering the H^+ concentration).

The Ca^{++} now attracted to negative charges on fine soil particles (clay and organic matter) can exchange places with other positively charged nutrient ions, e.g. K^+, Mg^{++}, NH_4^+ (Figure 1). When these negative exchange sites attract basic nutrient ions instead of H^+s, those ions remain available to plant roots and the fertility of the soil is increased. In this way, limestone not only raises soil pH but it also increases the percent base saturation of exchange sites which increases the nutrient delivery power (fertility) of the soil.

Other lime materials also are used. Calcium hydroxide (slaked lime) and calcium oxide (burned lime or quicklime) contain more neutralizing power per pound of material and react in the soil more rapidly than ground limestone. Thus, while limestone will take two years or more to raise soil pH to the level desired, these other more reactive materials will do it within a few months. However, these liming materials are more expensive than limestone, are more dangerous to handle and have the potential to injure turf if applied directly to growing grass. Consequently, ground limestone is normally recommended as the material of choice for use on turfgrasses.

Using lime on turf

Because ground limestone requires about two years to achieve its full benefits, it is wise to think ahead when making lime applications. Lime works best when it is incorporated into the top six to ten inches of soil. For turf, this can only be done prior to seeding or laying sod. If the soil is acid, incorporating ground limestone thoroughly within the top soil is the most effective way to prevent acidity based problems. This is also a time when the more reactive liming materials can be used with no concern over injuring turf. These materials will raise soil pH more rapidly than ground limestone. Phosphate fertilizer can be incorporated into the soil prior to seeding because it also is difficult to distribute throughout the root zone once the turf is in place. Distributing lime and phosphate fertilizer throughout the root zone will help insure rapid establishment of a strong and deep root system. Other major nutrients are more mobile in the soil and can be applied effectively after the turf is in place. The amount of limestone to apply should be based on a soil test and, prior to establishment, there is little concern over applying too much at one time.

The relationship between pH and the H^+ concentration of solutions

pH	H^+ concentration moles/liter	Acidity level
0	1.0	Strong acid
1	0.1	Strong acid
2	0.01	Highly acid
3	0.001	Highly acid
4	0.000,1	Very acid
5	0.000,01	Acid
6	0.000,001	Mildly acid
7	0.000,000,1	Neutral
8	0.000,000,01	Mildly alkaline
9	0.000,000,001	Alkaline
10+	0,000,000,000,1-	Highly alkaline

Established turf presents more of a problem for pH adjustment. Surface applications of liming materials will reduce acidity of the surface soil but deeper layers will take much longer to respond. The best approach is to apply lime regularly, no more than 25 to 50 pounds per 1000 sq-ft at a time. If calcium hydroxide or oxide forms are used, use less than 25 pounds per 1000 sq-ft per application. Larger rates will cause turf burning especially when temperature and humidity are high. For surface application, these more reactive liming materials offer no real advantage. Monitor soil pH via soil test and if a declining trend is evident, increase annual lime use preferably by making more frequent applications. Lime can be applied at any time of the year. Early spring and late fall are good because less disruption of turf use will occur then and natural incorporation through rainfall is more likely. Applying lime to frozen ground is fine so long as run-off is not likely. Run-off has rarely been observed on turf but it can occur when the soil is frozen and water infiltration is prevented. Applying lime to snow is risky especially if the snow might be blown into drifts. It is also more difficult to observe a uniform application pattern when the ground is white.

With spring hard upon us and soil test in hand, now is a good time to consider your liming program. If your soil pH is between 5.0 and 6.0, a lime application is warranted. Even if the soil is between 6.0 and 6.5, light maintenance applications are probably justified. Remember, response to lime will be slow so it is best not to wait until a serious acidity problem is before you. Use a fine grind of limestone even if it is a little more costly. It will provide more rapid results even when used as a surface application. Dolomitic limestone ($CaCO_3 + MgCO_3$) is recommended unless your soil analysis reports a high magnesium level. Magnesium is a macronutrient which is not likely to be supplied in fertilizer and may not be provided in significant amounts in top dressing materials. Dolomitic limestone is the least expensive way to provide this element which is essential for healthy grass growth.

Both calcium and magnesium are essential for grass growth. Ground limestone provides these nutrients while it maintains soil pH within an optimal range. For the expense and effort involved, regular lime applications may be among the most cost effective management tools available to the turf manager. ■