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WHY TURFGRASS RESPONDS TO PROPER USE OF LIME AND SULFUR COMPOUNDS

By Dr ELIOT C. ROBERTS
Turfgrass Specialist,
Iowa State University,
Ames, Iowa

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Phosphorus

Soil pH has a great effect on the availability of phosphorus to plants. Phosphates are most available from pH 5.5 to 7.5. Above and below these levels phosphates are tied up with other minerals and their availability is reduced. Under acid conditions iron and aluminium phosphates are formed. The solubility of iron and aluminum compounds increases as soils become more acid until they are readily soluble at pH levels from 4.5 to 5.0. Under these conditions the iron and aluminum react with phosphorus and convert it to a form which plants cannot use.

At pH levels above 7.5 phosphates again become less available. It is believed that under these conditions phosphorus is tied up as insoluble calcium phosphates which are unavailable for plant use. In the pH range 5.5 to 7.5 calcium phosphates of a type which are more mobile and available for plant use are formed. Within this range it is likely that the ability of the root to absorb sufficient phosphorus is more responsible for nutritional status of the plant than the availability of soil and fertilizer phosphorus.

It should be noted that at very low soil pH levels increased solubility of aluminum, iron, copper and manganese may result in higher concentrations of these elements than can be tied up with phosphorus. In such instances toxicity to plants may develop. Aluminum toxicity may become particularly serious as excessive amounts of this element are absorbed and precipitated in the conducting tissue as aluminum hydroxide. Deficiencies of copper, zinc, iron and manganese are more likely to occur under akaline soil conditions.

Potassium

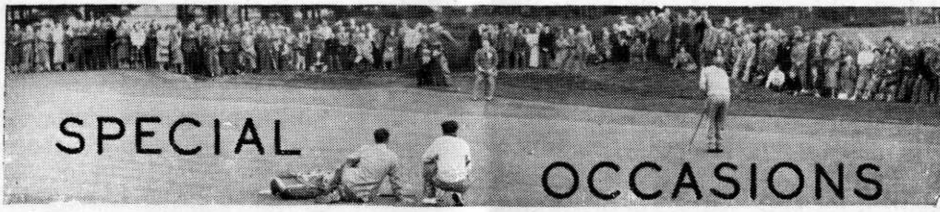
The availability of potassium does not change to any great extent over the normal soil pH range. There is some indication that heavy liming has reduced availability slightly and that under acid soil conditions potassium leaches from the root zone more readily.

Calcium and Magnesium

Calcium availability increases as soils become less acid and more alkaline. In general the quantity of calcium available in the average soil at pH 4, 5, 6, 7, and 8 is relatively as 1 : 4 : 8 : 14 : 22 respectively.

Magnesium availability increases as soils become less acid and more alkaline up to pH 8.5 after which it decreases. In general the quantity of magnesium available in the average soil at pH 4.5, 5.5, 6.5, 7.5, and 8.5 is relatively as 1 : 2 : 3 : 4 : 2½ respectively. The rate of increase for magnesium over the pH range of soil is therefore much smaller than for calcium.

Under acid soil conditions calcium and magnesium may be deficient and as such contribute to unsatisfactory plant growth.



AUG. 9-10-11th	**Annual Tcurnament, Whitley Bay.**
SEPTEMBER 12th	**Autumn Tournament, Southern Section, Moor Park Golf Club.**
14th	**Northern Section, Annual Match v. Sheffield Section, Scarcroft Golf Club.**
14th	**North West Section, Autumn Meeting, Manchester Golf Club.**
16th	**Midland Section, Autumn Tournament, Bloxwich Golf Club.**
29th	**East Midland Section, Autumn Tournament, Birstall Golf Club.**
29th	**Welsh Section, Autumn Tournament, Neath Golf Club.**
OCTOBER 7th	**S.G.G.A. West Section, Autumn Meeting, Pollock.**
19th	**Northern Section, Autumn Tournament, Leeds Golf Club.**
29th	**Midland Section, Annual Dinner, King's Head Hotel, Bearwood.**

Manganese and Iron

Besides soil pH, soil air and water content, degree of soil compactness and soil organic matter are related to availability of iron and manganese. Since plants require only small amounts of these two nutrients for satisfactory growth, toxicity from their over abundance may be as great a problem as deficiency from their short supply. Excess supply is likely to occur under extremely acid conditions while deficiencies are usually noted within the pH range 7.5 to 8.5. At high pH levels iron deficiency may occur because of an unfavourable iron-calcium balance within the plant which renders the absorbed iron ineffective. In this instance sufficient iron is absorbed, but utilization is prevented.

These deficiencies occur more on sandy soils than on heavier soils and are more likely to be noted in spring and early summer than later in the year.

How to make Soils less Acid

When soil pH levels drop below 5.8, treatments should be made to elevate the pH to 6.5-7.5. Lime is the material most often used for this purpose. Calcitic limestone contains calcium carbonates. Dolomitic limestone contains calcium carbonates and magnesium carbonates (equivalent to 15 to 20 percent magnesium oxide). Limestone may be broken down into calcium oxide and carbon dioxide. Calcium oxide is called quicklime. Quicklime plus water yields hydrated lime. Hydrated lime and quicklime are more soluble and faster acting than ground limestone. Mixtures of finely ground limestone and hydrated lime are called Agricultural lime. Actually soil acids in the presence of limestone or hydrated lime produce calcium and magnesium ions which are attracted to the clay particles in exchange for hydrogen ions which react with the carbonate to form carbonic acid. Carbonic acid is weak and slowly breaks up to form carbon dioxide and water.

The chemical composition of lime determines its neutralizing power. The relative neutralizing power of lime has been calculated on the basis of pure calcium carbonate being equal to 100 percent. Accordingly

100 lb. of calcium carbonate
74 lb. of calcium hydroxide
88 lb. of magnesium carbonate
56 lb. of calcium oxide
40 lb. of magnesium oxide —

all have the same value in correcting soil acidity. The following tables give percent neutralizing value and lb. equivalent to one ton of calcium carbonate.

In addition to chemical composition the particle size of lime affects its reaction in the soil. The finer the particles the faster they react; the coarser the particles the slower they react. A good lime should have some fine particles for immediate reaction and some coarse particles to add residual effect to a treatment. In general a reasonably fine limestone will have a particle size analysis similar to the following:

100 percent through a 10 mesh[1] screen
75 percent through a 50 mesh screen
60 percent a 100 mesh screen

In using these materials it is well to remember that hydrated lime is fine and thus more soluble in water and faster acting. It is more likely to burn and should never be applied on fairways at rates larger than 50 lb./1,000 square feet. Heavy applications at one time cause the soil at the surface (where the majority of turfgrass roots are located) to become too alkaline. This may tie up phosphorus, iron and other minor elements until the reaction works down into the soil. It is far better to make several smaller applications of lime (25 to 50 lb./1,000 square feet) and change the soil pH gradually than it is to change it abruptly with one large application. In general the finer the grind the lighter the application or the coarser the grind the heavier the application. Also, applications of finely ground material should be made more often because lasting effects are not as great. Very coarse material may be used on fairways at rates from 150 to 200 lb. per 1,000 square feet. On the basis of fine ground limestone, a safe rule to follow is — increase the rate of application 25 to 50 percent for coarse materials and reduce it 25 to 30 per cent for hydrated materials.

Material	**Molecular Weight**	**Neutralizing Value — %**	**Lb. Equivalent to 1 ton Calcium carbonate**
$CaCO_3$ Calcium Carbonate	100	100	2,000
$MgCO_3$ Magnesium Carbonate	84	119	1,680
$Ca(OH)_2$ Calcium Hydroxide	74	135	1,480
$Mg(OH)_2$ Magnesium Hydroxide	58	172	1,160
CaO Calcium Oxide	56	178	1,120
MgO Magnesium Oxide	40	250	800

Late fall, winter, and early spring are the best times to lime. Treatments made while the soil is frozen in the winter usually work well. Spreading lime at this time keeps additional spreader traffic off the turf during the growth season. Never use hydrated lime on fairways at more than 25 lb. per 1,000 square feet during the summer. If necessary other limes may be applied at standard rates during the summer. Never use hydrated lime before or after the application of a fertilizer containing ammonia. The lime will activate the fertilizer and produce ammonia gas which is extremely toxic to turfgrass. It is desirable to lime well in advance of making applications of phosphorus and arsenic. Where treatments with these materials follow closely, an application of lime, they will be less effective because of increased fixation in the soil.

Putting greens should be limed with

[1] *Ten openings per linear inch;* 100 *openings per square inch.*

fine ground limestone at from 10 to 50 lb. per 1,000 square feet. Hydrated lime should not be used on greens at rates in excess of 20 lb./1,000 square feet. Where greens have become scalded during the summer, anaerobic soil conditions may be cleaned up with applications of 2 to 5 lb. of hydrated lime per 1,000 square feet. Treatments may be made every week until a total of 10 lb./1,000 square feet has been applied. The material may be mixed with sand to increase ease of spreading.

In addition to lime, gypsum (calcium sulfate) may be used to supply calcium to acid soils. The effect of gypsum on soil pH is one of initial aciduation followed by a tendency for the pH to rise. Soils with poor structure which are slow to drain have been improved by applications of gypsum. Seventy-five to 100 lb. of gypsum per 1,000 square feet worked into wet spots in fairways have helped correct some poor drainage areas.

What determines how much Lime is needed

Since the concentration of hydrogen ions in the soil is responsible for its acidity it is necessary to consider both those ions attached to soil particles as well as those in soil solution. Hydrogen ions in solution constitute the active acidity of a soil. Hydrogen ions attached to soil particles make up the reserve acidity. If only sufficient lime is added to neutralize the soil solution, hydrogen ions will quickly be exchanged from the soil particles to the solution and the pH will return to an acid reading. Only where sufficient lime is applied to neutralize both the hydrogen ions in the solution and on the soil particles will a significant change in soil pH be brought about.

A measurement of soil pH gives only an indication of active acidity. It is necessary to run a lime requirement test in order to accurately evaluate the total acidity (active plus reserve acidity) so that the proper amount of lime may be applied. Lime requirement tests show that a sand and a clay soil may have the same pH but the clay soil requires more lime to bring about a given change in soil pH.

Thus heavier soils and soils with higher percentages of organic matter have higher lime requirements. As soils increase in the percentage of small particles contained (for example sandy soils to loamy soils to clay soils) increasing amounts of lime are required to counteract the reserve acidity. As soils increase in the amount of organic matter, they contain (for example sandy soils of low organic matter to sandy soils of medium organic matter) the quantity of lime required to neutralize the reserve acidity becomes greater. Actually the silt and clay and humus fractions on a soil serve as a buffer system which causes these soils to resist change in pH. Once limed to the proper pH level, they will be more stable and become acid more slowly than lighter textured soil of low organic matter content.

Finally, the more acid the soil the greater amount of lime required to raise the pH to a desired level. These relationships may be noted in Table 2.

Lb. Sulfur/A	Lb. Sulfur/1,000 sq. ft.	Reduction in Soil pH
100	2	0.20
250	5	0.40
500	10	0.70
1,000	20	1.20

How to make Soils more Acid

Soils which have high pH values can be made more acid by the application of fertilizers containing ammonium nitrogen. This can be accomplished over a period of time on tees and greens by applying from $\frac{1}{4}$ to $\frac{3}{4}$ lb. nitrogen per 1,000 square feet per application. Frequent treatments are usually necessary to provide adequate nitrogen levels over the entire growth season. Attempts to increase the amount applied at each treatment so that the frequency of applications may be reduced often result in foliar burn or in the production of over succulent turf which is subject to injury from adverse climatic conditions. Applications of fertilizers containing ammonium nitrogen may be applied dry with a whirl-wind type spreader or may be spread with a proportioner using water as a carrier. In either case the fertilizer should be washed from the foliage and into the soil immediately following application to each green or tee.

Aluminum sulphate has been used to acidulate the soil; however, rates of application for turf have not been well worked out. This material can be extremely toxic to plants and its use on turf is not generally recommended.

Flowers of sulfur or powdered sulfur may be used effectively to acidulate the soil. It has been used on putting greens and tees where pH levels have been too high for best growth of turfgrasses. Most uniform application may be made by mixing the sulfur with sand or topsoil as a carrier and by spreading the mixture with a whirl-wind type applicator.

It is important that exactly the right amount be applied since sulfur decomposes to form sulfuric acid which in large amounts may produce severe injury to turfgrass stands. Tests with a very fine sandy loam soil to which powdered sulfur was mixed at rates from 100 lb./A to 1,000 lb./A produced the following results:

It was found that the maximum effect of the sulfur on reducing soil pH was evident within one month from the date of application. Tests with heavier soils and with soils higher in organic matter indicate less effect than on the lighter soils with lower organic matter contents.

Applications on turf should not exceed 5 lb./1,000 square feet. Treatments should be made in spring and fall rather than during summer months. Test strips on a turf nursery are advised prior to treating greens. These will enable a careful standardisation of rate of application with existing grass and growth conditions.

Since disease organisms are often more active under acid soil conditions, particular attention should be directed toward disease identification and fungus control during periods of soil acidulation with powdered sulfur.

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PREDICTION

When one day at Heaven's gate
St Peter meets the Coach,
He'll hear "Now Peter, get this straight—
It's all in the approach"!

—Anita Raskin