

Turf Grass TRENDS



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Keys to good soil chemistry: pH and nutrient ions

by Christopher Sann

FROM A PRACTICAL TURFGRASS MANAGEMENT standpoint, the complex world of soil chemistry boils down to the study of two subjects: **relative acidity or alkalinity of the soil** (its pH) and **plant nutrient ions**.

Measured on a scale 1 to 14 with 7 representing neutral, pH determines the availability of plant nutrient compounds in the soil. Turfgrass plants must compete for nutrients in an environment of natural and manmade factors that can work both for and against the plants at each particular site.

Most turfgrass managers may not think of themselves as ion farmers, but even "naked-eye" practice is based on moving huge numbers of tiny packets of beneficial nutrients down through the underlying layers of macroscopic, microscopic and chemical compound levels down to atomic level. Soil chemistry makes that level visible—so the fundamental features and factors stand out—and field analysis and decisions can be based on scientifically determined facts. To be sure, there are complexities that need untangling: how nutrient ions react to each other and to the full range of forces at work in the primordial soup that we call soil and, most importantly, how their characteristics and activities affect the survivability of turfgrass plants. But the reward is that managed turf, whether it is maintained at low, medium or high levels, always benefits from good soil chemistry.

The soil acts as both the physical anchor for turfgrass plants and as a reservoir of naturally occurring and supplementally applied plant nutrients. These elements, the basic building blocks of plant tissues, are often held in the soil matrix in forms that cannot be readily used by the plants. They are "fixed" in unavailable forms and only become available through the effects of the forces of weather, degradation and decomposition.

Turfgrass managers, armed with an understand-

ing of soil chemistry and how it affects plant health and growth, represent a powerful force for improving turfgrass performance.

What are the essential plant nutrients?

TO SURVIVE, turfgrasses require sixteen essential nutrients—in various concentrations and amounts. The relative importance of each nutrient in plant development and survival can be gauged by their grouping as—**macronutrients and micronutrients** (see chart below).

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Essential plant nutrients

Elements	Available Forms & Ion Charges
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Macronutrients

Carbon (C)	CO ₂ ⁼ , CO ₃ ⁼
Hydrogen (H)	H ⁺
Oxygen (O)	Many forms
Nitrogen (N)	NH ₄ ⁺ , NO ₃ ⁺
Phosphorus (P)	HPO ₄ ⁼ , H ₂ PO ₄ ⁻
Potassium (K)	K ⁺
Sulfur (S)	SO ₄ ⁼
Calcium (Ca)	Ca ⁺⁺
Magnesium (Mg)	Mg ⁺⁺

Micronutrients

Iron (Fe)	Fe ⁺⁺ , Fe ⁺⁺⁺
Manganese (Mn)	Mn ⁺⁺
Boron (B)	H ₂ BO ₃ ⁻
Copper (Cu)	Cu ⁺⁺
Zinc (Zn)	Zn ⁺⁺
Molybdenum (Mo)	MoO ₄ ⁼
Chlorine (Cl)	Cl ⁻

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Taking soil samples

SOIL SAMPLING—collecting soil for laboratory testing—is the first step in the process of determining the levels of plant nutrient elements at a particular site. Accurate soil testing and interpretation of the results begins with the proper techniques for sampling. Any mistakes made in sampling can lead to improper management strategies and wasted time and money.

Where sampling is done depends on the type of information the turfgrass manager is seeking. General sampling is done on a site or sites where the topographic, management, use, and environmental conditions are similar. Problem site sampling should be done where information about a specific site or problem area is needed.

General and problem area sampling

GENERAL SAMPLING is done to get an overview of nutrient levels and their balance over a large site(s) with consistent conditions. General samples should be taken so that they are representative of the whole site and should not include any soil from any problem areas within the sampling site. The number of samples taken from any given area within a site should be relative to the relationship of the square footage of the area to the total square footage of the site. For example, if the site can be divided into three areas A, B and C, and the relationship of the square footage of each area is 3 to 2 to 1, then three samples should be taken from area A, two from area B and one from area C.

Consistently following this practice will assure that sampling will accurately reflect the nutrient levels of the whole area at the time of testing and that comparison of current and future testing results will provide an accurate long term picture of the nutrient levels of that site.

Specific or problem area sampling is done to areas of limited size within a site, which have specific conditions that are different enough from the general site conditions that the area exhibits symptoms inconsistent with the whole site. Problem-area sampling should be done only when the other possible causes of turfgrass decline (insect, diseases, traffic,

compaction, management, etc.) have been eliminated. Sample cores should be taken in a uniform manner and only from within the problem area. Also, another separate test sample should be taken from just outside the problem area, to provide a comparison.

Sampling volume, depth, and frequency

THE MINIMUM AMOUNT OF SOIL that is needed for testing is about one cup. If you are sampling from a large site with 30 to 50 cores, the individual cores can be thoroughly mixed and the one cup sample can be obtained from the mixture. On smaller sites, the minimum number of cores that should be taken is seven or eight.

The soil sample should be taken where the largest mass of roots for a particular species occurs. The following table illustrates where in the soil profile the mass of roots occurs for bluegrass, bentgrass and bermudagrass.

Percent of root mass profile

Depth	Bluegrasses	Bentgrasses	Bermudagrasses
0" -3"	89%	83%	80%
3" -6"	7%	13%	12%
6" -9"	4%	4%	8%

For all three species most of the root mass occurs in the top three inches; therefore, sampling should be confined to the top three inches of the soil profile. Try to avoid including cores that are less than three inches in the sample, if possible. If three inch cores are not available, then increase the number of cores in the sample to compensate for the lost soil volume.

In established, stable, well-balanced higher C.E.C. soils (>15) [see "Terms to Know" on page 10] bi-annual sampling should be enough. In less stable, established but well-balanced lower C.E.C. soils (<15) annual sampling is necessary. In poorly balanced soils, no matter what the C.E.C., annual or semi-annual sampling is essential. Where monitoring of just soil pH is required, sampling can be done two to four weeks after an amendment application has been made. Newly constructed or renovated areas should be monitored up to four times a year, as nutrient levels will change rapidly in these unstable soil conditions.

NO MATTER WHAT SITES you are testing and no matter which techniques you are using, be consistent. Once you have selected the boundaries of a sampling site, do not change them. Once you have established a sampling technique for a site, do not change. The information in soil test reports is only as good as the sampling techniques that you employ. ■



Where are plant nutrients held in the soil?

PLANT AVAILABLE NUTRIENT IONS are in a constant state of change within the soil. Some of the ions that can be used by turfgrass plants are held at ion exchange sites. These sites are located on clay, organic matter (including root surfaces). Other ions become fixed in compounds with other chemical elements. These ions are held within the soil matter complex or in the liquid soil solution.

Nutrient ions, which are held at exchange sites, can be stripped away into the soil solution by other ions. Once in the soil solution, they may be used by plants, they may become reattached at other exchange sites, or they may be leached from the plant root zone.

A soil test reports provides a "snapshot" of plant nutrient ion levels in the soil reservoir at a fixed point in time:

- THE CURRENT NUTRIENT ION BALANCES
- THE CONCENTRATIONS OF THOSE NUTRIENT IONS
- AND THE pH, which is one of the controlling factors for turfgrass nutrient availability.

By identifying nutrient imbalances, the report helps turfgrass managers gauge the effects of fertilizer and soil amendment applications made to correct those imbalances. They also can help project the long-term effects of turf management strategies.

Sampling techniques and testing choices

SOIL SAMPLING ON SITE IS THE FIRST STEP—and often the most neglected part of the process. A "mis"-taken or "mis"-timed soil sample can give an inaccurate picture of the forces at work, leading to inappropriate fertilizer and amendment applications that can require considerable time and energy to counteract. Where, how, and when samples are taken can have a significant effect on the outcome of soil tests (see "Taking soil samples" on page 2).

Soil testing procedures and the resulting soil test reports vary in the number and types of specific nutrient tests that are made on submitted samples. The number and types of nutrients tested depend on the plant species being grown, the amount of detail requested, and the testing facilities' capabilities.

Turfgrass managers should make sure that the testing done to their samples is appropriate for the turfgrass species that they manage. Testing that is appropriate for agricultural crops may not be appropriate for turf, and testing that is appropriate for turf may not be appropriate for annuals, perennials, and shrubbery. Also, because the nutrient requirements of different turfgrass species vary, testing designed for turfgrasses should allow managers to differentiate between turfgrass species or mixtures of species.

Generally, a good soil test report, focused on the macronutrients, should report the following:

SOIL pH
BUFFER pH
AVAILABLE PHOSPHORUS
EXCHANGEABLE POTASSIUM
EXCHANGEABLE MAGNESIUM
EXCHANGEABLE CALCIUM
EXCHANGEABLE SODIUM
C.E.C. (Cation Exchange Capacity)
% HYDROGEN BASE SATURATION
% POTASSIUM BASE SATURATION
% MAGNESIUM BASE SATURATION
% CALCIUM BASE SATURATION
% SODIUM BASE SATURATION

If micronutrients tests are reported, then the following results should be available:

AVAILABLE ZINC
AVAILABLE MANGANESE
AVAILABLE COPPER
AVAILABLE IRON

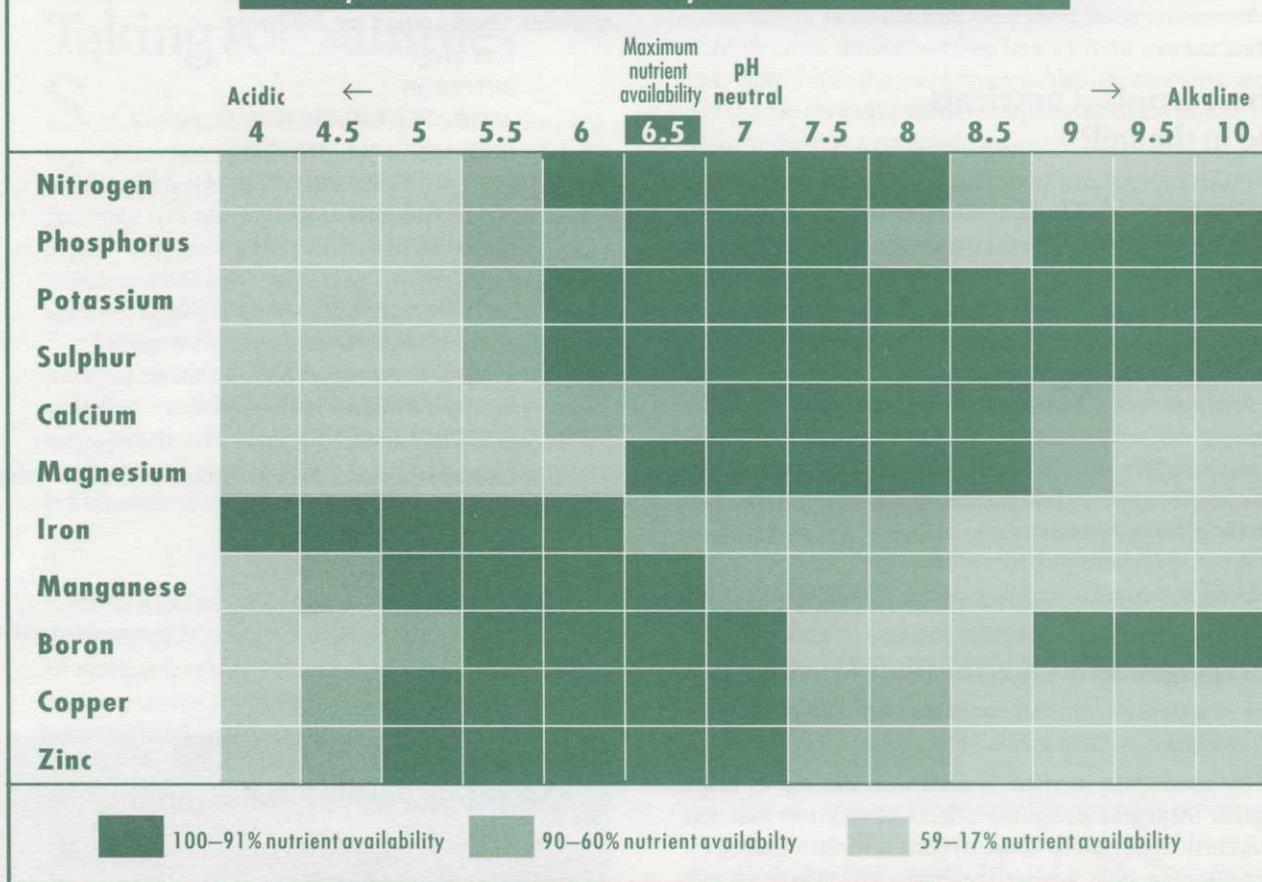
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Additional tips on soil sampling

The following techniques apply no matter what information is being sought:

- SAMPLING CAN BE DONE any time the soil is not frozen.
- ABOVE GROUND, UNDECOMPOSED THATCH that has no roots growing in it should not be included.
- THATCH THAT IS DECOMPOSED and has a substantial portion of roots growing in it should be included.
- PLASTIC BUCKETS AND MIXING UTENSILS should be used to collect large multi-site composite samples.
- AVOID USING ANY GALVANIZED UTENSILS or buckets in taking or mixing cores as they may contaminate the samples.
- WAIT AT LEAST TWO WEEKS after a fertilizer or amendment application before sampling.
- REMEMBER THAT pH READINGS are generally higher in cool weather.
- CLEAN ALL SAMPLING EQUIPMENT after each sample is obtained, as residues from one site can affect the results for another site.
- ESTABLISH A CONSISTENT METHOD and frequency of testing so the results of repeated testing can be accurately compared. ■

Soil pH and nutrient availability of 11 essential elements



The key factor controlling plant availability of nutrients

OF ALL SOIL TEST RESULTS, soil pH is the most important measurement. Perhaps the best way to understand how pH plays its role in the soil matrix is to remember that soil is a mixture of minerals, organic matter, water and air. Plant nutrient ions are exchanged and absorbed by the roots through the water film that covers the roots and other solid elements in the soil. Soil pH is the controlling factor for most of these ion exchange activities (*see "Terms to Know" on page 10*).

Ion exchanges depend on the electrical charge of the ions involved and the location of the exchange sites. Exchanges involving negatively charged anions (*see "Terms to Know"*) usually occur on either the positively charged soil organic matter or on the surface of the roots themselves. Exchanges involving positively charged cations (*see "Terms to Know"*) usually occur on the mineral, clay or organic matter portions of the soil or on the root surfaces. No matter which ions are exchanged or absorbed, the essential ingredient for the exchange process is water, and the factor in the water that controls these exchanges—and the plant availability of key nutrient ions—is the soil pH.

There are two measurements of pH: soil pH and buffer pH. Soil pH measures the concentration of free hydrogen ions (H⁺), which provides a gauge of the active acidity of the soil

solution. The buffer pH measures the concentration of hydrogen ions that are held on exchange sites and is a gauge of the soil's reserve acidity.

Soil pH or active acidity has a dramatic effect on plant nutrient availability, and that can have a dramatic effect on plant health (*see above chart*.) As the soil pH decreases below 7.0 (neutral) to 6.5 and becomes slightly acidic, the availability of some plant nutrients starts to become restricted. As the soil pH decreases to 5.5 and below, there is a significant reduction in all of the major plant nutrients' availability. This reduction in nutrients can have significant effects on long-term plant survivability. As soil pH increases above neutral, the same reduction in plant nutrient availability starts at 7.0 and becomes as significant at 7.5 as it is at 5.5. Maximum plant nutrient availability occurs at a soil pH of 6.5.

Effects of soil pH

■ Low soil pH

PLANT SURVIVABILITY can be significantly compromised, under low soil pH conditions, because:

- THE MAJOR PLANT NUTRIENT PHOSPHORUS becomes fixed into unavailable compounds with aluminum and iron.

Soil pH measures the concentration of free hydrogen ions (H⁺), which provides a gauge of the active acidity of the soil solution.

- AT SOIL pH LEVELS BELOW 5.0, the minor elements zinc, copper, manganese, boron and molybdenum are restricted.
- AS SOIL pH LEVELS DECLINE, more hydrogen ions occupy exchange sites, reducing the number of locations at which plants can obtain nutrients.
- WITH HYDROGEN IONS OCCUPYING exchange sites, highly soluble forms of nitrogen fertilizers can rapidly leach out of the plant root zone and into the ground water.
- DUE TO INCREASED LEACHING that occurs at low soil pH levels, potassium, calcium and magnesium levels can be significantly reduced.

■ High soil pH

LIKE LOW SOIL pH, high soil pH causes a restriction of essential plant nutrients, because there is:

- INCREASED LEACHING of plant available forms of nitrogen, ammonium (NH₄⁺) and nitrate (NO₃⁻).
- INCREASED VOLATILIZING OF NITROGEN, above a soil pH of 7.2, as ammonia gas (NH₃). When lost into the atmosphere in significant amounts, ammonia gas can be toxic to turfgrass.
- INCREASED COMBINING of the major nutrient phosphorus and the secondary nutrient calcium, forming a plant unavailable salt.
- INCREASED LEACHING out of the root zone of the nutrients calcium, magnesium and sulfur.
- INCREASED FIXING into plant unavailable forms of the minor nutrients manganese, iron, zinc and copper.

Severe restriction in plant nutrients, caused by either low or high soil pH, essentially starves the turf. When both the nutrients that are naturally available and the nutrients that are applied as fertilizer are leached out of the root zone or fixed into plant unavailable compounds, the turf's ability to replace normal leaf and root tissues and to recover from the adverse effects of drought stress, insect attacks and disease damage is severely compromised. This reduced recoverability leaves a turf stand open to perennial and annual broadleaf weed and grassy weed invasion and can leave large turf areas predisposed to disease problems. If the nutrient restriction is severe enough and prolonged enough, it can eventually kill an entire stand of turf.

How do soils become acidic or alkaline?

IT IS NOT UNUSUAL FOR SOIL pH LEVELS to change over time. This degradation is caused by both natural and man-made forces. For example:

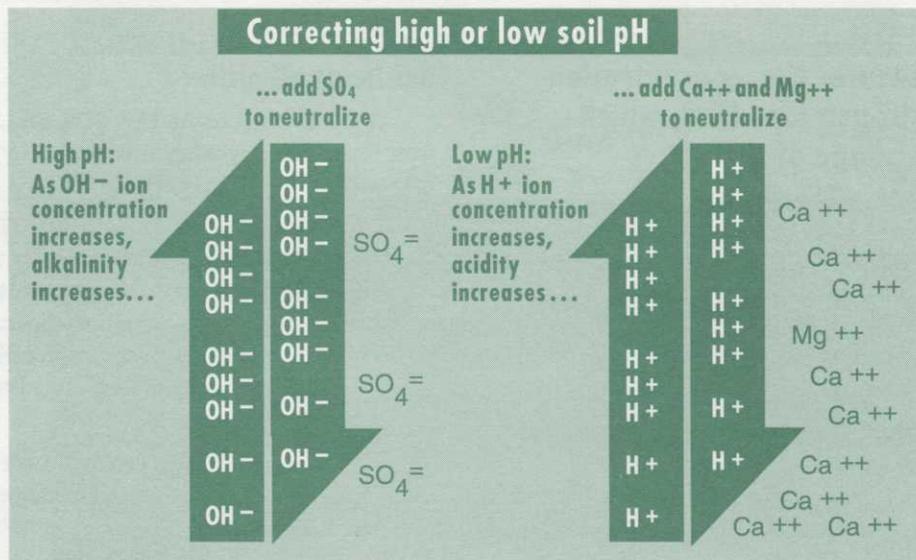
- WATER-SOLUBLE ALKALINE NUTRIENT IONS, particularly calcium, which normally neutralizes acidic soils, leaches out of the soil plant root zone with normal rainfall and irrigation. As these alkaline ions are stripped from their exchange sites and leached out of the soil solution, they are replaced by hydrogen ions, and the soil becomes more acidic.
- AS ORGANIC MATTER DECOMPOSES, it produces hydrogen ions that replace alkaline nutrients on the exchange sites.
- AS PLANTS TAKE UP NITROGEN, the roots release hydrogen ions which lower the surrounding soil pH.
- MANY FERTILIZERS PRODUCE AN ACIDIC soil reaction when applied. Some fertilizers are so strong in their reaction that as much as one ton of calcium carbonate is required to neutralize each ton of the fertilizer.
- THE GASEOUS EXCHANGE OF CARBON DIOXIDE at the roots produces carbonic acid. Carbonic acid is produced by the reaction of carbon dioxide and water. The acid then dissociates into an hydrogen ion and hydrogen bicarbonate—with the bicarbonate leaching out of the soil root zone and leaving the soil acidic.
- NATURALLY OCCURRING HIGH LEVELS of sulfur also react with water to produce sulfuric acid and release hydrogen ions.
- THE GREATLY INCREASED ACIDITY of the rain in several parts of the country, due to man-made pollution, also contributes to soil acidification.

Since soils generally tend to become more acidic over time, the reasons that soils tend to become more alkaline are limited:

- EXCESSIVE LIMING when done as a standard practice rather than on a recommendation based on a soil test may leave soils alkaline.
- DECOMPOSITION of naturally occurring calcareous materials provides a continuous supply of both calcium and magnesium—a common problem in soil overlaying natural limestone deposits.
- USE OF IRRIGATION WATER that contains high levels of calcium, magnesium and sodium will also increase soil pH.
- DRY SOILS OR SOILS that receive little irrigation or rainfall tend to retain a number of toxic alkaline salts that are the by-products of normal turfgrass respiration, which leave the soil alkaline.

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Correcting high or low soil pH



Good soil chemistry
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Correcting soil pH

SINCE NUTRIENT AVAILABILITY is so dramatically affected by both low and high soil pH and restricted plant nutrients can have such long-term detrimental effects on plant health, controlling soil pH is of primary importance.

When soil pH and buffer pH are low, there is a high hydrogen ion concentration. To break the strong ionic bonds of hydrogen on the exchange sites and in the soil solution, strongly alkaline materials based on calcium and magnesium must be applied. When recommended amounts of alkaline materials are applied, the soil matrix is flooded with strongly alkaline calcium and magnesium ions. They dislodge and replace the hydrogen ions there, leaving the soil pH closer to neutral.

The most common materials that are used to reduce soil acidity are oxide, hydroxide or carbonate forms of calcium and magnesium. Since the carbonate forms (represented by ground limestone) are the most efficient, the cheapest, and the most abundant, they are the most commonly used materials.

When soil pH levels are high, above 7.0, there is a high concentration of hydroxyl ions (OH⁻) in the soil solution and a high concentration of calcium, magnesium and sodium ions on both soil and root exchange sites. Elemental sulfur is applied to lower alkaline soil pH.

When elemental sulfur is applied to lower soil pH, it reacts with water and oxygen to form sulfuric acid. The sulfuric acid then dissociates into hydrogen ions and sulfate ions (SO₄⁼). The hydrogen ions neutralize the hydroxyl ions by reacting to form water and the sulfate ions, which are either used by the plants, in this plant available form, or they leach out of the root zone.

pH and soil characteristics

THE PRACTICE of controlling the natural tendency of soils to become acidic does not simply affect plant nutrition. It also plays a significant role in the physical structure of soil.

Calcium and other positively charged soil ions are involved in **soil particle flocculation**. Flocculation is the process whereby positive soil ions are attracted to, and attach to the outside of, negatively charged soil particles, primarily clay. As the outside of these soil particles becomes "covered" with positively charged ions, they are "flocculated."

Flocculated soil particles, with their outside coating of positively charged ions, tend to repel other flocculated soil particles. This process temporarily produces a loose soil structure with good to excellent soil pore spaces that allow for better water percolation and gaseous exchanges, and provides openings in which root hairs can grow without restriction.

If, when soil particles are flocculated, there is a sufficient supply of humic acid, a by-product of the decomposition of soil humus or organic matter, then a process called **aggregation** can occur. Unlike soil particle flocculation, soil particle aggregation is a very stable form of soil structure. It is a primary reason why large, stable areas of grasslands have occurred on most of the continents. This form of ecosystem is made more stable by the fact that grasses produce more pounds of humic acid per acre than any other vegetative crop.

Stable as natural turfgrass stands may be, managed stands of turf are far more homogeneous and more above normal demand intensive and, at least in part, therefore, more fragile. That is why benign neglect does not produce acceptable or predictable levels of managed turfgrass performance. Not establishing and maintaining a near neutral soil pH and a good balance of all of the plant nutrients essential to turfgrasses is a sure recipe for disaster—no matter how intensely that turf is managed. Putting the case in positive terms, a working knowledge of basic soil chemistry can help turfgrass managers make correct and timely fertilizer and amendment applications and provides a way of checking the results and making sure the desired results are obtained. ■