Alkaline soil conditions are often responsible for chlorotic turf. A high soil pH can tie up nutrients, particularly iron and phosphorus.

Acid — To Inject or Not to Inject

You don't need a Ph.D. to know your pH.

by HAROLD F. HOWARD, Ph.D.

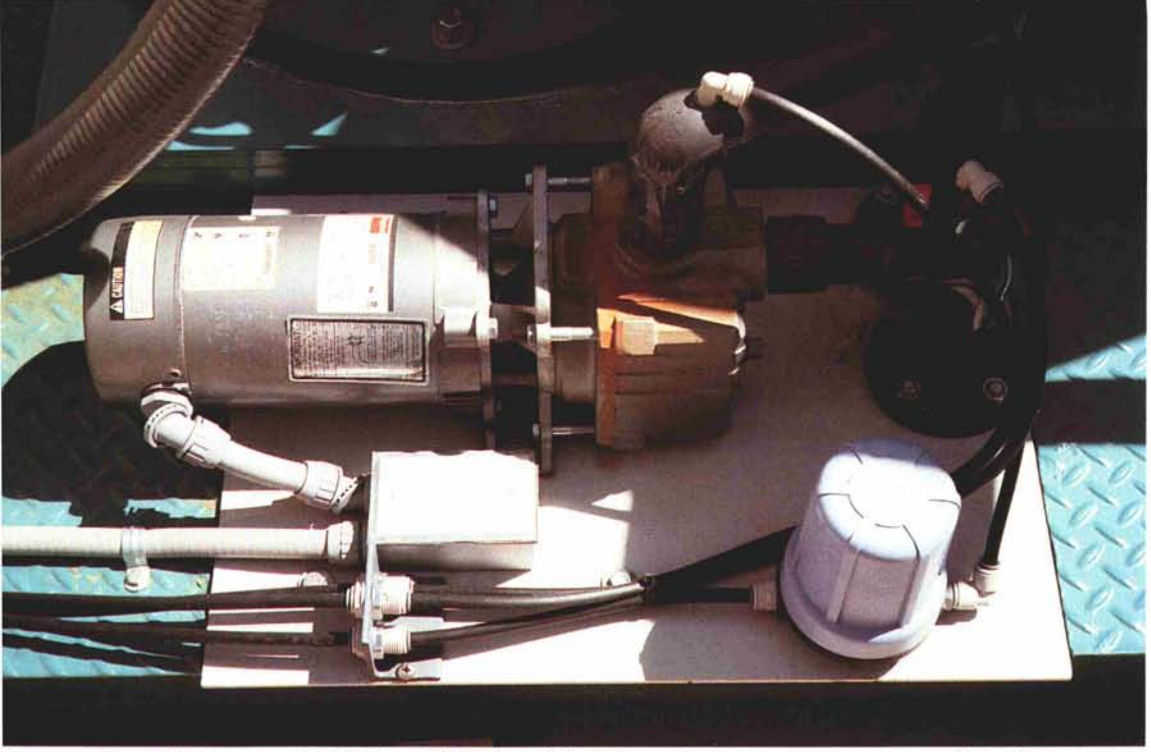
IT HAS BEEN generally accepted for decades that pH is the single most important chemical factor that influences soil suitability for successful agriculture. Turfgrass managers have long strived for pH 7.0, the *neutral* pH at which the soil is neither acidic nor basic. The benefits of adjusting a high or low soil pH value to neutral abound in literature, and include increased nutrient availability, reduced sodium hazard, increased water infiltration, and increased tilth.

A quick chemistry refresher reminds us that pH is a measure of the hydrogen ion (H^+) concentration in a soil solution. Acidic soils (pH below 7.0) have a high concentration of H^+ ions while basic soils (pH above 7.0) have a low concentration of H^+ ions. A turf manager in a temperate climate, where soils are typically acidic, will add lime ($CaCO_3$) to the soil to raise the soil pH. The added lime reacts with the H^+ ions and removes them from the soil solution, raising the soil pH toward neutral.

Turf managers in arid climates, such as the southwestern United States, usually find the opposite situation. Typically, their soils are basic, with pH values above 7.0 and often as high as 9.0. These soils usually contain a high lime content as well. To lower soil pH toward neutral, the turf manager will add either acid or an acid-forming amendment to increase H^+ ions in the soil solution. When the amendment is added, the acid reacts with the lime in the soil and is consumed by the following reaction:

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$$
(Equation 1)

Such soils are said to be buffered because they resist a lowering of pH when acid is added. When dealing with a high pH soil, the best that the turf manager can hope for is to lower the



To avoid damage, the pH electrodes should be mounted in a remote location. When the microprocessor control system detects different readings between two electrodes, the system automatically shuts down.

pH of the surface layer. To neutralize the soil to a great depth would require an unreasonable quantity of acidifying amendment.

Is An Acidifying Amendment Appropriate?

If the pH of your soil is above neutral 7.0, then your turf may benefit from lowering the soil pH. Maintaining a near-neutral pH changes a variety of factors that will affect management conditions.

1. Nutrient availability: Most nutrients become less available as the soil pH deviates from 7.0. Prominent examples are phosphorus and iron. Reducing the pH from 8.0 to 7.0 may result in a many-fold increase in the availability of these nutrients, possibly eliminating the need for supplemental fertilizers.

2. Sodium hazard: Many soils in arid climates contain high levels of sodium, which can cause many problems. One way to reduce sodium is to add gypsum ($CaSO_4$). The added Ca^{2+} ions effectively displace sodium (Na^+) from the cation exchange sites, allowing the Na^+ ions to leach from the rootzone. However, if your soil is calcareous (high in $CaCO_3$), as most are, application of gypsum is not necessary. Addition of an acidifying amendment will react with the $CaCO_3$ as in Equation 1. In this process gypsum ($CaSO_4$) is manufactured in the soil and the pH of the soil is lowered. For example, addition of 19 lbs. of elemental sulfur to calcareous soil will produce 100 lbs. of gypsum ($CaSO_4$).

3. Water infiltration: As sodium is displaced from the cation exchange sites, the soil particles tend to form aggregates. This causes the soil pores to become larger, which in turn increases the rate at which water moves through the pores. After acidification, the infiltration rate of basic (high pH) soils usually increases substantially.

4. Lime reduction: When present in soils, lime acts as a cement between soil particles, just as it binds larger aggregates in concrete. When the lime content of a calcareous soil is very high, the soil is known as caliche, a very hard form of impure limestone. After adding an acidifying agent, lime will be reduced as in Equation 1. Over a period of time, enough lime can be eliminated so that calcareous soil becomes quite soft and agriculturally productive. Also, with high pH irrigation water, lime can precipitate inside plumbing, a situation referred to as *hardening of the arteries*. This leads to reduced flow or even plugging of pipes, sprinklers, and drip emitters. Injection of acid will eliminate these lime deposits.

The above factors are potential benefits from adding acidifying amendments to a basic soil. However, if your soil is neutral or acidic, you do not need more acidification, so don't do it. Ignore salesmen who tell you otherwise. Addition of acidification amendments where they aren't needed will cause your situation to take a step backward rather than forward.

Acidifying Amendments

Acidifying amendments are applied to mature turf in one of two ways: addition of concentrated acid to irrigation water, or the application of an acid-forming material directly to the turf. As a liquid, acid is injected into irrigation water as it enters the pumping system. This addition lowers the pH of the irrigation water, and subsequently the soil pH is lowered. Sulfuric acid (H_2SO_4) is the most popular material used for this purpose, although other acids (often a blend of sulfuric acid and urea) are sometimes used. The user should examine the cost efficiency per unit of neutralizing power when using blended materials.

An acid-forming amendment is not acidic when it is applied, so it can be spread directly onto mature turf in dry form. Once in the soil, the amendment undergoes a reaction by which it is converted to sulfuric acid, which then lowers the soil pH. This amendment is commercially prepared as 90 percent elemental sulfur dust combined with 10 percent bentonite clay. The material is compressed into small pellets which can be spread easily. When damp, the pellets disperse into sulfur dust. The sulfur dust is then oxidized by *Thiobacillus*, a soil-borne bacterium, to form sulfuric acid as follows:

$$S_2 + 3O_2 + 2H_2O \rightarrow 2H_2SO_4$$
(Equation 2)

Whether supplied to the soil directly or indirectly, the intended results of the acidifying amendment applications are identical — lowering the soil pH. It is worth noting, however, that one pound of elemental sulfur will oxidize into three pounds of sulfuric acid. As a result, spreading one ton of elemental sulfur will have the same acidifying effect as injecting three tons of sulfuric acid. This is important in determining which material is more cost-effective in lowering soil pH at your course. Incidentally, both elemental sulfur and sulfuric acid are byproducts of the petroleum refining and metal ore smelting industries.

The Spread vs. Inject Decision

Both acidifying amendments and methods will reduce soil pH. The method that is most appropriate for your particular facility is based upon the following considerations.

1. Cost efficiency: If your objective is to neutralize 1,000 lbs. of lime, you have the choice of using either 320 lbs. of elemental sulfur or 980 lbs. of sulfuric acid. A recent survey of vendor pricing indicated that 93 percent sulfuric acid sold for $115 per ton and 90 percent elemental sulfur sold for $240 per ton. The cost difference to neutralize 1,000 lbs. of lime would be $43 using elemental sulfur or $61 using sulfuric acid. A modern injection system typically costs about $8,000, but is sometimes provided at no expense by the acid supplier.

2. Labor and intrusion: When using modern injection equipment, minimal labor costs are incurred. Visual inspections of the equipment, ordering acid supplies when needed, and electrode calibration every two to three months are all that is required to maintain the equipment. Acid injection is not visible or detectable to the facility users. Spreading of dry elemental sulfur requires applicator labor costs and the use of equipment. This involves higher costs and also may be intrusive to the golfers.

3. Application uniformity: When using the injection method, the uniformity of the application is only as good as the irrigation uniformity. In many cases this can be quite poor, especially with older, less sophisticated or poorly tuned systems. Under these circumstances, the areas receiving the least irrigation coverage are usually those needing the most amendment.

With dry materials, application uniformity should be excellent. In practice, the application is only as good as the skill and effort of the operator and the quality of the equipment.

4. Segregation of areas: Based on the site conditions, it may not be necessary to apply amendment to the entire facility. For example, the turf manager may not wish to apply amendment to the greens or locations where the soil pH does not need lowering. When routine injections are made, these areas will not be segregated and will receive the amendment. With dry application, the manager has better control over which areas receive the amendment.

5. Risk of overdose: When making a dry application, there is a risk of overdose. If the buffering capacity of the soil is low or if the application technique is poor, it is possible that the pH can be reduced to undesirably low levels. For this reason, application of dry materials to a high-sand-content green could be very risky. On the other hand, modern injection systems are designed to lower the pH of irrigation water to approximately 6.5. Given proper equipment function, there is no potential for lowering the soil pH below 6.5.

Modern Injection Systems

With the recent advent of modernized equipment, acid injection has changed from a very risky to a relatively safe endeavor. For example, when John Szklinski became superintendent of the Desert Highlands Golf Club, he inherited an injection system that consisted of little more than a pH electrode in the wet-well, a controller, and a pump to deliver acid from a storage tank to the wet-well. During his second week, John noticed that the 1,000-gallon acid storage tank was nearly full one day but empty the next. He discovered that the electrode had broken and the controller had dumped the entire acid supply into the wet-well. The wet-well then backflowed into the reservoir and lowered the reservoir pH to 2.4. Employees told him that the reason no fish had died was because they were all killed by a previous malfunction. Though no turf loss resulted, a multitude of ductile iron fittings had begun leaking and concrete in the system had likely eroded. This experience is typical of early systems with inadequate safety features.

John contacted Werecon, Inc., in Scottsdale, Arizona, a manufacturer of state-of-the-art injection equipment for a replacement system. The new system is designed not only for performance, but also for safety. All acid-handling components are installed above the storage tank and are double-enclosed. At no point in the system is the acid under pressure, so there is no opportunity for ruptured fittings or having an uncontained leakage occur. Rather than dumping acid into the wet-well, a circulator pump removes water from and returns it to the wet-well via open discharge. Acid is injected into the downstream flow as needed. The system utilizes two pH electrodes, one in the wet-well and the other in the pump stream. All components are monitored and controlled by a computer, which is programmed to adjust the water pH to 6.5. If at any time the computer detects a component failure, a pH outside the operational range, a discrepancy in readings between the two electrodes, or any other abnormality, the system is automatically shut down. These modern systems serve their owners with relatively safe and reliable operation.

In summary, if you need to lower your soil pH, two amendment strategies are available to you. However, these should not be employed if your soil is not in need of acidification. A careful evaluation of your particular circumstances will aid in selection of the most appropriate choice.

This acid reservoir is located in an underground vault for public protection. By removing the acid through the top of the tank, accidental spills from leaky fittings are avoided.

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