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Balancing Soil Nutrients

by Joel Simmons

In recent years, the art of turf management has started to "move underground". Superintendents all across the country, and the world, are rediscovering the importance of good soil management. The benefits being reported include reduced disease pressure, better turf vigor and reduced dependency on high nitrogen salt fertilizers. These results are realistically achievable if you "Balance Chemistry and Feed the Soil."

Tom Parent and I have outlined some of these ideas over the last several issues of *TurfNet Monthly*. It was suggested by several superintendents that we take this to the next level and bring together the principles of soil chemistry, biology and physics. Not until these are looked at as one entity can real change be made in soil management.

Soil is an extremely dynamic biological, chemical and physical being, like the human body. There are tens (if not hundreds) of thousands of species of microorganisms in any one soil, many of which both feed and protect the plant. Recent university research has spawned an entire industry dedicated to inoculating soils with beneficial microbes. This has helped to rekindle our interest in soil biology as it relates to the health of the plant and the ultimate success of a turf program. However, to create an environment for a healthy population of soil microbes the chemistry of the soil must first be balanced.

Relationships count

The concepts of calcium and magnesium were discussed at length in the December issue. Clearly, there is more to good plant nutrition than simply calcium and magnesium—but to start with the important Ca:Mg ratio was by no means a mistake. When building a good soil fertility program it helps to put aside a few of the old standards (such as pH, NPK and the plant itself), and focus on the soil. By balancing soil chemistry, pH falls in line and the plant receives the nutrition it requires.

Since calcium and magnesium make up 80% of the base saturation, it makes sense to give them top consideration. As they reach ideal percentages, hydrogen is allowed to saturate 10% of the soil colloid — which will leave the soil with a pH of 6.0 - 6.5, depending on the soil testing laboratory. Focusing *solely on pH*—and not the *relationship between the cations*—will often lead to misapplication. Not until the soil chemistry is balanced will the soil physically open up and provide air and water to needed soil microbes. Understanding this concept makes it easier to see the importance of bringing chemistry, biology and physics into line as one entity.

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THE MACRO NUTRIENTS

Calcium and Magnesium

These nutrients are often considered secondary nutrients and therefore of lesser importance. In fact, they should collectively saturate 80% of the soil colloidal sites. Calcium is used more in weight and volume than any other nutrient. However, an excess of calcium will cause magnesium, phosphate and trace nutrient deficiencies. In biologically poor soils, typical of many golf course soils, calcium is very immobile and foliar supplements are needed.

Magnesium is essential to good plant growth because it controls the development and biochemistry of the chlorophyll molecule. It aids in phosphate metabolism and helps to activate several enzyme systems. If excessive, however, it can create a "gluing" effect on the soil and cause phosphate, potash and nitrite deficiencies. High magnesium and low calcium levels in soils allow organic matter to decay into alcohol, which can suppress bacterial populations. Wherever native soil characteristics allow, the relationship between calcium and magnesium should be adjusted to 7:1 with a base saturation of 68% Ca to 12% Mg. This will lead to a physically and biologically healthy soil.

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Phosphorus

Phosphorous is perhaps the most misunderstood of all the basic plant nutrients. An anion, phosphorous is very reactive and often tied up in the soil with calcium and other cations. These calcium-phosphate bonds are often very hard to break, especially in biologically weak soils, leaving the plant deficient. Phosphorous is found in all plant tissue but is most pronounced in the seeds, flowers and youngest shoots. It is the backbone of many enzyme and amino acid systems, including photosynthesis. It regulates the breakdown of carbohydrates and energy transfer. Without phosphorous, cell division is weakened and plant growth suffers. These deficiencies can lead to plant stress, susceptibility to disease, insect attack, and even weed infiltration.

Interestingly, the turf industry has decided that phosphorous levels should be restricted. This misconception stems from limited research done many years ago that indicated excessive phosphorous encouraged the growth of *Poa annua*. Another issue is the *source* of phosphorous. To obtain soluble phosphorous, rock phosphates are acidified to produce super- and triple-super phosphate, diammonium phosphates and monoammonium phosphates (MAP). With the possible exception of MAP, these are very reactive forms and tend to tie up in the soil quickly.

In an attempt to re-mineralize the soil, rock forms of phosphate are gaining in popularity. Both hard rock and soft rock phosphates are being used as soil amendments to help condition the soil and provide a slow release form of phosphorous. Some research has shown that these minerals are as (or more) available than the soluble forms when chemical tie up is taken into account. Regardless of the form, phosphorous is typically deficient in the plant, and foliar applications can be beneficial.

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Potassium

Potassium is often referred to as "the band director". It helps to direct free nutrients (such as carbon, hydrogen and oxygen) out of the atmosphere and into the plant. Without this activity photosynthesis would be severely restricted and the plant would struggle to make starches, sugars, proteins, vitamins, enzymes and cellulose. Potassium aids in helping the plant through the cold of the winter and the heat of the summer.

In short, when potassium is out of balance plant stress is very high. However, one of the great fallacies in our industry is that you can not overdo potassium. You can overdo everything!

Potassium is a positively-charged cation and should saturate only 3-5% of the soil colloid. When too much potassium is used, other important cations suffer, most notably calcium and magnesium. In fact, potassium can drive pH more aggressively than magnesium or calcium by quickly replacing them and creating an imbalance in base saturation. Potassium tends to be relatively mobile in the plant. When excesses occur, not only does the soil suffer, but imbalances are created intra-cellularly and stress is actually created. As soil pH climbs above 6.5, potassium mobility slows down, and as the soil reaches 7.0 mobility is severely hindered.

Common potassium sources in commercial turf fertilizers are potassium sulphate and potassium chloride. Typically, potassium sulphate provides the best reaction in the soil because potassium must often compete with excessive amounts of calcium or magnesium for colloidal sites. Sulfur assists the potassium in chemically exchanging with excessive calcium or magnesium. Muriate of Potash (potassium chloride), on the other hand, has one of the highest salt indexes of all commercial fertilizers — possibly ten times the amount of chlorine used in chlorinating municipal water. Imagine what that could do to beneficial bacteria in the soil.

Sulfur

Sulfur is perhaps the orphan child of the plant nutrient world. Considered a secondary or even a trace nutrient, sulfur is actually needed in the same amount as phosphorous. It is used to make proteins, amino acids and enzymes. Although sulfur does not exist in chlorophyll, it plays a role in its formation. Soil test results from the typical golf course often reveal sulfur levels well below the desired 25 PPM (50 lbs. per acre) level.

Both phosphorous and sulfur are anions, but phosphorous is stronger than sulfate in the soil and often wins the battle for absorption sites. As is true with all anions in the soil, sulfur relies on soil microbes to be converted into plant-usable forms. The soil colloid, which is mainly the combination of humus and clay particles, is negatively charged. Since anions are also negatively charged, they are repelled from the colloid and remain primarily in soil solution. In biologically weak soils, sulfur mobility is significantly reduced.

Heavy industry and acid rain have historically supplied all but the most rural areas ample amounts of sulfur. Today, with higher air pollution standards and industry moving overseas, less sulfur is available "naturally", so it must be applied to soils in the form of calcium -, potassium- or magnesium sulphate.

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Sul-Po-Mag is a mineral form of sulfur that can supply as much as 57% sulfur as well as potassium and magnesium. The problem is that too little is retained in the soil unless a Ca:Mg imbalance makes the soil too tight to allow them to flush through. Sandy soils and sand-based greens also have difficulty retaining sulfur because of their high leachability.

Nitrogen

It is important to discuss both the benefits and the consequences of this nutrient. Clearly, nitrogen is one of, if not *the*, most important nutrient in growing turf. It accounts for 15 to 20% of all plant proteins and is an integral part of most physiological functions. Without nitrogen there would be no photosynthesis and, therefore, no plant. However, nitrogen is also the most *overused* nutrient in our industry, and the negative impact it can have on the soil can be tremendous.

One of the lectures that too many of us fell asleep through in our college agronomy class was the one on the "Carbon to Nitrogen Ratio", which described the relationship between the available carbohydrates (Carbon) and proteins (Nitrogen) in the soil. The C:N ratio should be approximately 10:1. Soil microbes need both for their metabolism, but they 'always eat at the table first.' This means that any nutrient introduced to the soil is first digested by micro-organisms before the plant has a chance to eat. This can be explained easily using the nitrification diagram, which looks like the following:

Urea > ammonia (NH3) > nitrite (NO2) > nitrate (NO3) > into the plant

(The arrows in this diagram represent soil microbes which are responsible for breaking down the nitrogen fertilizer into plant-usable forms.)

When soluble nitrogen is introduced to the soil, microbes have to work over time to break it down. They need energy in order to do this, and obtain that energy from the available fractions of soil organic matter or humus. As nitrogen is applied over time, more and more humus is used up to provide the energy to break down the this protein... and an imbalance of C:N occurs. This process of "burning out the soil" weakens future populations of beneficial bacteria and aids in the proliferation of disease pathogens.

Turf plants generate plenty of carbon though the growth of the root systems, but this organic matter is mostly long-chained ligneous material (such as thatch) and is not readily available as a quick source of energy.

We typically measure the success of our turf programs by the color of the turf. For the most part, the color we look for is derived from a certain amount of nitrate — regardless of how much nitrogen has been applied. The difference is the effectiveness of the nitrification by the soil microbes.

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As the C:N ratio is weakened, more and more nitrogen is needed to provide the amount of nitrate to generate that perfect green color. Most of the excess nitrogen either vaporizes or leaches through the soil profile. There are successful golf course superintendents getting by with as little as one pound of nitrogen per 1000 square feet per season on heavy clay soils. They succeed only because they have balanced their chemistry and fed their soils.

Making sure that calcium and magnesium ratios are correct and then providing the soil with available carbohydrates (such as composted organic materials) will allow any turf manager to reduce the amount of supplemental nitrogen needed. In turn, biological activity of the soil will improve, helping to keep pathogens in check and optimizing the availability of nutrients to the plant.

Trace Nutrients

The trace nutrients of boron, iron, manganese, zinc and copper are included in the soil audit by the better testing laboratories. These are vitally important nutrients that are used in very small amounts by both the soil microbes and the plant. In fact they are needed in amounts measured in parts per million (ppm). The ideal ranges include:

- boron: 1-2 ppm
- iron: 150 - 200 ppm
- manganese: 40 - 120 ppm
- zinc: 6 - 20 ppm, and
- copper: 2 - 15 ppm.

When comparing these numbers to the ideal of 3000 pounds per acre of calcium you can see what small amounts of these nutrients are needed.

Trace nutrients are extremely important in the formation of amino acid and enzyme systems that allow for the transfer of energy in both the soil and the plant. For example,

- boron is required for the translocation of sugar and helps regulate salt, water and nitrogen assimilation in the plant.
- Iron works as a carrier of oxygen required in the production of chlorophyll. This is why iron provides a greening effect when applied to the plant.
- Manganese is involved with the oxidation and reduction reactions in the plant that aid in carbohydrate metabolism.
- Copper helps to form many different proteins, amino acids, enzymes and organic compounds and is critical in the process of root metabolism.

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- Zinc aids the plant in water absorption and is essential for proper metabolism of many micro-organism including the nitrogen-fixing azotobacter.

There are very definitive relationships between all the soil nutrients. When these relationships become imbalanced, nutrient mobility suffers. The pH of the soil also effects the mobility of soil nutrients. As the pH of a soil falls below 6.0 the availability of such nutrients as phosphorous, boron, copper, zinc and molybdenum starts to fall off, and below 5.0 mobility all but stops. Above a pH of 7.0 copper, zinc, manganese and iron all slow down very quickly.

There are relationships between nutrients such as potassium and boron, where if potassium levels start to rise boron mobility drops. Iron and manganese should be in a 1.5 to 1 ratio. If manganese levels creep above the iron levels the mobility of iron falls off and plant photosynthesis suffers. Iron also suffers in calcarious soils or soils that have calcium base saturations into the 70 or 80 percentile.

Copper suffers in very rich organic soils. If the soil becomes water-logged, manganese can not mobilize into the plant.

Perhaps the greatest factor in slowing down the mobility of nutrients in the soil is the lack of sustainable levels of beneficial micro-organisms. When the biology of the soil is weak, which is very typical on a golf course, nutrient mobility slows down and plant stress can result.