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Fertility Programs for Sand-Based Rootzones

Turfgrass managers today have a wide array of fertilizer products to choose from when making nutrient management decisions. The development of an appropriate fertility program for sand-based rootzones is of paramount importance. Recent regulations in Minneapolis barring the use of phosphorus fertilizers on home lawns, and obligatory nutrient management plans for farms in Maryland, foreshadow increasing scrutiny of golf course fertilizer usage and nutrient fate. Turf managers must obtain knowledge of their site, assimilate information on available fertilizer formulations, and apply the selected products in a manner that optimizes turfgrass performance.

This paper will address a few of the issues crucial to an understanding of nutrient management in sand-based rootzones. First, knowledge of chemical properties in sand root zones is essential. Next, turfgrass managers must assess nutrient status in the root zone, and determine fertility requirements. Products and application methods that meet identified fertility needs must be selected. Finally, products can be applied and effects of the treatments can be monitored.

An important example of sand-based rootzones are golf course greens constructed to specifications published by the United States Golf Association. This construction method provides aeration, resistance to compaction, and excellent drainage. However, the specifications are for soil physical properties, and do not take into consideration chemical properties of the soil such as nutrient holding capacity.

Soil amendments are often added during construction to modify the physical and chemical properties of the root zone. Addition of organic amendments can increase water and nutrient holding capacity of sands. Inorganic

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In the laboratory, various chemical extractants are used to remove nutrients from the soil sample. The amount of nutrients removed varies with the extraction procedure used. However, the amount of nutrient extracted, regardless of the method, should correlate with a desired plant quality so that fertilizer recommendations can be developed.

Experiments measuring the leaching of potassium from sand root zones found an exponential decrease in leaching as CEC increased from less than 1 cmol kg^{-1} to 6 cmol kg^{-1}. As CEC was raised above 6 cmol kg^{-1} in this experiment, little change was observed in potassium leaching. This indicates that for minimal leaching of potassium, the optimum CEC in sand greens may be at least 6 cmols kg^{-1}.

amendments, such as zeolite, a silicate mineral, also increase the nutrient and water holding capacity of sands.

Cation exchange capacity (CEC), represented as centimoles of negative charge per kilogram of soil (cmols kg^{-1}), is an indicator of a soil's ability to retain positively charged nutrients such as potassium and calcium. Because sand is inherently low in CEC, organic matter provides the majority of CEC in sand-based rootzones.

The CEC levels in sand-based rootzones are limited by the desired physical properties of the sand root zone. USGA Guidelines call for root zone total porosity of 35-55%, air-filled porosity of 15-30%, and saturated conductivity (water) of 6-12" hour^{-1}. The addition of organic matter or other amendments to sand root zones can increase nutrient and water holding capacity, but organic matter also serves to slow water infiltration and percolation while decreasing the air-filled porosity.

When organic matter is added to sand on a weight basis, 1-3% organic matter by weight generally meets the USGA-specified guidelines, while 4% or higher amounts of organic matter mixed with the sand may not meet USGA specifications. Because desired nutrient holding characteristics in the root zone have to be balanced with necessary physical properties, CEC values in sand greens at the time of construction are typically less than 5 cmols kg^{-1}. Experiments measuring the leaching of potassium from sand root zones found an exponential decrease in leaching as CEC increased from less than 1 cmol kg^{-1} to 6 cmol kg^{-1}. As CEC was raised above 6 cmol kg^{-1} in this experiment, little change was observed in potassium leaching. This indicates that for minimal leaching of potassium, the optimum CEC in sand greens may be at least 6 cmols kg^{-1}. However, because CEC levels in sand root zones are often less than 6 cmols kg^{-1}, care must be taken when nutrients are applied. In order to maintain plant health without stimulating a growth flush, and to prevent leaching of nutrients from the root zone, nutrients must be applied either at very low rates, or in a controlled release form.

Before selecting fertilizer products and application strategies, it can be very helpful to obtain more information about the putting green system by conducting soil nutrient analysis (soil test) and plant analysis (tissue test). Careful analysis of test results is essential in understanding the implications of the tests.

A typical soil test will provide analysis of pH, phosphorus, potassium, calcium, and magnesium. Other parameters often reported include CEC, organic matter, sulfur, sodium, and micronutrients such as iron, copper, zinc, and manganese. Soil nutrient analyses do not typically test for nitrogen, because nitrogen in a moist soil is in flux. Tests for soil nitrogen are not an effective predictor of future nitrogen availability. Tissue tests can provide an accurate reading of nitrogen fertility, but most turfgrass managers rely upon experience and turfgrass monitoring to determine nitrogen requirements.

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Unfortunately, few calibration studies relating soil nutrient analysis to turfgrass growth response and turfgrass quality have been performed. Additional calibration studies relating various components of turfgrass quality to soil nutrient analysis and tissue analysis results, and particularly studies that evaluate nutrient interactions, are needed. Sufficiency levels for tissue nutrient concentrations have been published, but they do not always correlate with sufficiency levels for nutrients in the soil. An investigation of soil test levels and tissue nutrient concentrations for turfgrass growing in sandy soils has suggested tissue analysis may be more effective than soil nutrient analysis for determining the nutrient status of turfgrass.

Even with its shortcomings, soil nutrient analysis remains a valuable tool for evaluating soil nutrient levels. However, because many of the nutrient extractants and fertilizer recommendations were developed for mineral soils, and considering the limited number of calibration studies completed in turfgrass, soil nutrient analysis may be most useful as an indicator of trends in soil properties.

Other methods exist for monitoring nutrient status of putting greens without sending soil or tissue sample to a laboratory. Measuring clipping yield is an effective way to monitor growth,

Light, frequent fertilizer applications utilize liquid sources to increase precision.

which can serve as an indicator of nutrient status. Evaluation of turfgrass color is another method that can be used to determine fertilizer needs. Certain diseases that are more prevalent at certain nutrient levels or imbalances can indicate nutrient needs as well.

After evaluating the root zone properties and existing nutrient status, fertilizer products and application methods can be selected. For example there are a few factors that distinguish fertilizer selection from other turfgrass areas. The inherently low nutrient holding capacity of sand root zones steers one in the direction of light, frequent applications. The low cutting height of most greens precludes usage of regular sized granular products, so specially formulated granular products must be used. Also, a slow, steady growth rate is usually desired for playability reasons, so again either controlled release products or light and frequent applications are usually desired.

There are essentially two ways to apply fertilizer to putting greens. Products can be applied that will enter the soil and eventually be available to the plant roots, or products can be applied to the foliage and be taken up into the leaves. The foliar application method fits very well with the desired goal of light and frequent applications. A lot of confusion exists surrounding the subject of foliar absorption of nutrients, and it can often be the subject of a seemingly endless debate. The mechanisms involved with foliar absorption are not fully understood, but numerous studies have been conducted, and some semblance of understanding can be constructed.

Foliar absorption of nutrients has been acknowledged for over 150 years, but the first definitive studies in the field were performed shortly after World War II with the advent of radioactive isotopes, which can be used as "tracers" in scientific experiments. The radioisotopes can be used to differentiate between nutrients taken up by the foliage, or nutrients taken up through the root system.

An important thing to remember is that nearly all the research and literature concerning foliar uptake of nutrients has been conducted on crops other than turfgrass. Certainly many of the mechanisms and experimental results may be transferable from these other species, but one can not be sure of results in turfgrass until more tests are performed. Golf course superintendents who have used foliar nutrition possess a great deal of practical knowledge concerning the efficacy of these products.

Plant leaves are covered with a waxy cuticle that serves as a diffusion barrier for the water and nutrients inside the leaf. The cuticle also prevents excessive leaching of nutrients from leaves during rainfall, heavy dews, or other wetting events. The presence of the cuticle poses problems for plant uptake of min-

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One wonders how the efficiency of foliar uptake relates to nutrient uptake from the soil. At least with nitrogen, there does not appear to be much of a difference. Studies investigating foliar absorption of various nitrogen sources applied to the leaves of ryegrasses and bluegrasses have found about 40% of the applied nitrogen absorbed by the leaves within 48 hours.

Nutrient analysis of the system should be conducted, either through monitoring plant characteristics or by submitting soil or tissue samples to a laboratory. The different fertilizer products, and the mechanisms of their uptake, need to be considered.

eral nutrients. The process of foliar absorption appears to consist of three steps: nutrient adsorption at the leaf surface, diffusion or penetration through the cuticular membrane, followed by cellular uptake within the leaf. The initial barrier to absorption is the cuticular membrane. Nutrients can enter the leaf through small pores in the cuticle, or via diffusion across the cuticular membrane. Stomatal entry is not considered to be a significant factor in nutrient absorption by leaves. The primary function of stomata is regulation of gas exchange with the atmosphere, and the stomata reach their greatest aperture during active photosynthesis, in full sunlight. A cuticular layer coats the interior of stomatal openings, so nutrients still face a barrier to absorption even if they somehow enter a stomatal pore. Studies have shown both increased uptake of solutes at night, when stomata are closed, and uptake of nutrients in the absence of stomata. We can conclude that nutrient absorption does not occur through stomatal openings in plant leaves.

Absorption rates have been determined for many nutrients applied to agronomic or horticultural crops. With nitrogen, up to 50% uptake of applied product can occur within 1 to 4 hours. For potassium, however, 50% uptake of applied product does not occur for 1 to 4 days. In 24 hours, 8% of applied iron has been taken up in beans.

These uptake rates may seem low. One wonders how the efficiency of foliar uptake relates to nutrient uptake from the soil. At least with nitrogen, there does not appear to be much of a difference. Studies investigating foliar absorption of various nitrogen sources applied to the leaves of ryegrasses and bluegrasses have found about 40% of the applied nitrogen absorbed by the leaves within 48 hours. Numerous studies examining nitrogen fate in soils have shown only 5% to 74% of applied N is actually recovered in the plant. One important consideration is that with equivalent nutrient concentrations in solution, the absorption rates for leaves are much smaller than the absorption rates for roots. The reason for this difference is the small size of the pores in the leaf cuticle, which restrict absorption.

So how does one maximize the efficiency of foliar applied nutrients? Increased humidity at the leaf surface improves nutrient absorption by leaves, most likely because it increases the diameter of the cuticular pores. Research has shown that different product formulations require different humidity levels to remain mobile and able to cross the cuticle. Once an applied product has dried on a leaf, the rate of absorption will decline, but subsequent increases in humidity will improve uptake of the remaining material.

Research has shown that organically chelated potassium is absorbed more readily than molecules.

What does all this mean for the golf course superintendent? Not all nutrients applied to turf, either as granular fertilizers or as foliar products, will be absorbed by the plant. Both types of product have their place in a nutrient management program, and foliar products can be an ideal way to spread nutrients evenly and at a low rate across putting greens. Foliar products can be ideal when limiting conditions prevent uptake of nutrients from the roots, or when a quick response to nutrients is required. Recent developments in granular fertilizer formulations have also significantly reduced mower pickup, and superintendents can utilize these products effectively as well.

The key to developing an effective fertility program for sand-based rootzones is consolidated knowledge of the entire system. The chemical properties of the root zone must be understood. Nutrient analysis of the system should be conducted, either through monitoring plant characteristics or by submitting soil or tissue samples to a laboratory. The different fertilizer products, and the mechanisms of their uptake, need to be considered. Once these three factors of a sand-based system are understood, turfgrass managers can focus on the most important facet of fertilization–the maintenance of an excellent turf surface.

Micah Woods
Graduate Research Assistant