Turfgrass Fertilization

Supplement only when needed to provide better turf and playability

BY BLAKE MEENTEMEYER AND BRIAN WHITLARK

Soil is a living, breathing environment that provides many of the building blocks required to sustain healthy turf growth. However, supplemental nutrition is typically necessary to strengthen critical plant components so turf can provide desirable playing surfaces. The judicious use of resources including fertilizer is a high priority in meeting the golf industry's goal of sustainability. When considering fertilizer programs, it is important to remember that they do not need to be expensive to be effective. A "back to basics" approach to fertilization was nicely described by the great golf course architect Dr. Alister MacKenzie when he said, "One cannot emphasize too frequently the importance of leaving God's gifts alone and never fertilizing unless it is certain that time and nature will fail to cure."[1] This article covers several aspects of turfgrass nutrition, such as determining how much fertilizer is actually needed, fertilizing for enhanced playability, the economics of turfgrass fertilization, and dispelling some of the myths surrounding fertilizer applications.

DETERMINING FERTILIZER REQUIREMENT

The first step in determining how much fertilizer should be applied to turf is assessing the nutrient status of the soil and comparing the results to established guidelines for sustainable turf nutrition. To do this, collect soil samples from representative areas of the golf course and submit them to a soil testing laboratory for analysis. There are many different methods of soil testing and a variety of guidelines for interpreting the results, so it can be difficult to decide which methods and guidelines to use. With the introduction of new soil test interpretation methods, now a simplified process is available that helps determine just how much fertilizer turf actually needs.

SLAN vs. BCSR — Is one method more effective than the other? The primary methods used to interpret soil test data are the sufficiency level of available nutrients (SLAN) method and a modified version known as the minimum level of sustainable nutrition (MLSN) method. The SLAN method attempts to quantify the amount of available nutrients in the soil and ranks the sufficiency level for individual nutrients from low to high. The nutrient sufficiency levels originally were developed based on crop response but have been modified over the years to better correlate with turfgrass response.

Another method for interpreting soil test data is the base cation saturation ratio (BCSR) method, which compares the ratios of calcium, magnesium, potassium, and sodium to what is found in an "ideal soil." A limitation of the BCSR method is that it often leads to overapplication of calcium and potassium in an effort to achieve an "ideal" cation ratio.[2 3 4 5] This is not to suggest that the BCSR approach will be harmful, at least in the short term, but it does not make agronomic or financial sense to apply nutrients for the sole purpose of achieving a set ratio when sustainability is paramount.

MLSN – Are you being sustainable? The MLSN method seeks to maintain turfgrass performance while managing soil nutrients at or slightly above minimum threshold nutrient values.[6] The minimum threshold values used by the MLSN method are based on 20 years of laboratory soil testing data from a wide range of golf courses. The integrity of the guidelines, originally based on approximately 17,000 samples, continues to improve as more soil samples are analyzed. The MLSN guidelines are representative of soils where turfgrass is performing well, and 90 percent of the soil samples contain nutrients at or above the threshold values necessary to maintain healthy turfgrass. To increase the robustness of the MLSN guidelines, golf course superintendents are encouraged to participate in the Global

CASE STUDY: IS SOIL SAMPLE DEPTH IMPORTANT?

Sample depth plays a key role in the decision-making value of any soil test. For example, a golf course in the desert of southern California was struggling with bermudagrass recovery from overseeding. Soil tests collected at a depth of 5 to 6 inches did not show any indication that turf health would be compromised based on nutrition, salinity, or soil pH. However, soil samples collected from the top 1.5 to 2.0 inches revealed a pH of 4.6, as opposed to the 5- to 6-inch depth sample that had a pH of 7.1. At such a low pH, the turf was suffering from nutrient toxicity. An application of calcium carbonate — i.e., lime — quickly raised the pH and turf health improved.

In another example, at a golf course irrigated with reclaimed water in southern Arizona, soil samples from the top 1 to 2 inches revealed paste extract electrical conductivity values of 4.8 decisiemens per meter (dS/m). Salinity values were only 1.8-2.0 dS/m in soil samples harvested from the 4- to 5-inch depth. In this case sodium and other salts had accumulated at the surface in the absence of leaching from rain or irrigation, a common situation in the Desert Southwest.

It is critically important to identify the relevant soil strata for testing and submit soil samples for chemical analysis that represent the individual layers. Such an analysis will provide better information for decision making.

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You can achieve excellent turf conditions with a simple, sustainable, and environmentally responsible fertility regimen.

Soil Survey for Sustainable Turf. The MLSN threshold values continue to evolve with the ongoing addition of samples; however, the most recent published guidelines are as follows:

- Maintain pH >5.5
- Potassium (K) 37 ppm
- Phosphorus (P) 21 ppm
- Calcium (Ca) 331 ppm
- Magnesium (Mg) 47 ppm
- Sulfur (as sulfate) (SO_4) 7 ppm

Tissue Testing — Does it really pass the test? Tissue testing is used less frequently than soil testing because, at present, there are insufficient data available to predict turfgrass performance based on tissue nutrient content. The effectiveness of fertilizer applications based on tissue testing, and their impact on the nutrient content within plant tissue, is poorly understood and unpredictable. However, tissue testing may reveal nutrient deficiencies that are not gleaned from soil test results.

For example, a potassium fertilizer application does not necessarily result in higher potassium levels in the plant or an improvement in turf performance. However, applying too much potassium can lead to lower calcium, magnesium, and iron content in plant leaves. Similarly, an overapplication of calcium will reduce potassium, magnesium, and iron in plant leaves. If tissue tests indicate a potential nutrient deficiency, consider applying the nutrient of concern to a small area and monitoring the results before expending time and resources on large-scale applications. To learn more about nutrient guidelines in turfgrass tissue, read the *USGA Green Section Record* article Micro-Managing.

How much fertilizer is right for your facility? Determining the appropriate amount of fertilizer for golf course areas involves comparing soil test results with turf performance. Start by calculating the amount of each nutrient required to reach recommended levels in the soil as suggested by Woods et al. Keep the fertility program simple and focus on maintaining essential nutrients above the recommended MLSN threshold levels. Keep in mind that nutrients are removed when clippings are harvested. Applying supplemental fertilization to account for the nutrients removed when clip-

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pings are collected will help maintain soil nutrient levels above MLSN recommended levels. This strategy offers a more sustainable approach to managing fertility inputs without compromising turf quality, recovery, or playability.

Step 1: Calculate the amount of fertilizer needed to correct a soil nutrient deficit. The amount of fertilizer required to correct a soil nutrient deficit can be calculated with soil test results and MLSN recommendations using the following equation:

Element (pounds per 1,000 square feet) = 0.05 x (desired ppm – observed ppm)

For example, if soil test results indicate that the soil has 20 parts per million (ppm) potassium, but MLSN guidelines recommend a soil potassium level at or above 37 ppm, the annual potassium fertilizer requirement to reach MLSN guidelines can be determined:

Potassium (pounds per 1,000 square feet) = 0.05 x (37 – 20)

Potassium (pounds per 1,000 square feet) = 0.85

Based on this example, 0.85 pounds of elemental potassium would be required to increase soil potassium levels to meet the minimum MLSN guideline of 37 ppm. Applying a 0-0-50 fertilizer at 2.04 pounds per 1,000 square feet will correct the potassium deficit.

Step 2: Calculate nutrients removed by collecting clippings. Turfgrass clippings contain nutrients that have been extracted from the soil during growth. When clippings are returned to the surface and allowed to naturally decompose, their nutrients are released and the soil is replenished. However, when clippings are collected, the nutrients extracted from the soil during normal plant growth are removed from the nutrient cycle. Therefore, to sustain soil nutrient levels, it is important to account for the nutrient removal that occurs when clippings are collected.

The amount of nutrients in grass clippings varies by grass species. Generally, cool-season turfgrass clippings have a nitrogen-to-phosphorus ratio of 8:1 and a nitrogen-to-potassium ratio of 2:1. Similarly, most warm-season grass clippings have a nitrogen-to-phosphorus ratio of approximately 3:1 and a nitrogen-to-potassium ratio of approximately 3:2, with the exception of seashore paspalum clippings, which have a nitrogen-to-potassium ratio closer to 1:1. Using these ratios and the fact that nutrient uptake by turfgrasses is driven by growth potential that can be estimated by the amount of applied nitrogen, the amount of phosphorus and potassium removed by clippings can be estimated. For example, for every 1 pound of nitrogen applied to cool-season turfgrasses, applying 0.125 pound of elemental phosphorous and 0.5 pound of elemental potassium is recommended to replace the phosphorus and potassium that is depleted by removing clippings.

As an alternative, superintendents may consider developing site-specific nutrient content ratios by collecting and analyzing clipping samples from well-performing areas.

Step 3: Determine annual nutrient application rate. Add the amount of nutrient required in Step 1 to the amount in Step 2, combining the amount of nutrient needed to correct the soil deficiency with the amount required to replace the estimated amount of nutrients lost by removing clippings.

ECONOMIC CASE STUDY

The USGA encourages golf courses to deploy a simple, scientifically sound, and cost-effective fertility program. In some cases, USGA agronomists have helped golf course operations save significant amounts of money through programs that reduce inputs and utilize elemental fertility products such as urea, ammonium sulfate, potassium nitrate, and calcium nitrate.

For example, one facility in the Las Vegas area was utilizing an expensive fertility program, spending around $90,000 annually on liquid fertilizer products for 4 acres of bentgrass putting greens. In 2013, nitrogen, phosphorus, and potassium were applied at 4.3, 1.7, and 12.9 pounds per thousand square feet, respectively. The bentgrass greens were healthy and had excellent playability. This particular superintendent was open minded and willing to experiment with an alternative, less-expensive plan as long as the health and playability of the greens were not compromised. In 2015, after two years of refining the new fertility program, annual nitrogen, phosphorous, and potassium applications were 4.3, 1.1 and 3.9 pounds per thousand square feet, respectively. Furthermore, the superintendent switched to a simpler product line, consequently saving 82 percent when compared to the 2013 budget. The course only spent $15,751 on fertilizer in 2015 for the same 4 acres of bentgrass greens and, most important, the putting greens have never been healthier — confirming Settle and Dernoeden's research findings that none of the expensive fertilizer programs were superior to that of urea and iron.

FERTILIZE FOR ENHANCED PLAYABILITY

Fertilizers play a critical role in maintaining playing quality. Turf that is overstimulated with fertilizer may look attractive, but it is likely to be spongy and soft. The ideal balance is to apply nutrients in a manner that encourages growth and recovery from normal wear without creating overly lush conditions.

Thatch — Can you regulate accumulation? Putting greens with an acceptable amount of surface organic matter will perform substantially better than those with excessive organic matter. Managing thatch and organic matter requires an integrated approach utilizing tactics such as sand topdressing, vertical mowing, core aeration, and applying adequate, but not excessive, amounts of nitrogen. Nitrogen should not be applied for turf color, but only to sustain healthy growth and allow for adequate recovery from pitch marks, golfer traffic, and maintenance operations. Applying an appropriate amount of nitrogen will limit the potential for excessive organic matter accumulation beyond the rate of microbial decomposition. Additionally, substantial nitrogen inputs — i.e., greater than 0.5 pound

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Fertilizer rates can have enormous implications on the playability of the rough. The golf ball on the left is sitting up and can be easily struck and advanced, whereas the golf ball on the right is engulfed in leaf material caused by excess fertility.

of nitrogen per 1,000 square feet — during aeration are discouraged. Heavy nitrogen inputs during aeration may expedite recovery, but they also could increase thatch production as core-aeration events are typically scheduled during peak growth periods to promote quick recovery.

Rough Fertilization — Less is more. Nitrogen inputs on golf course roughs should be minimal. Nitrogen should only be applied to rough when necessary for turfgrass health or to improve turfgrass density, where appropriate. Fairway fertilizer programs should not include adjacent rough. Overstimulating rough with fairway fertilizer applications results in thick, dense rough along fairway margins. This condition places an excessive penalty on shots that have only slightly missed the fairway. Making precision foliar fertilizer applications on fairways, rather than granular applications, makes it easier to avoid overfertilizing non-target rough. Dr. John Monteith described the negative effects of penal rough in his 1934 address entitled "Economies in Course Maintenance."[7] One section of Dr. Monteith's speech titled "Curtailing of Some Practices Yields Better Golf" references limiting rough fertilization. Remembering that the native soil often can provide most of the nutrients required for turf growth will help superintendents adhere to a "less is more" fertilizer philosophy.

Late-Season Fertility — Do the benefits outweigh the risks? Late-season fertility can assist with winter plant hardiness and improve turf density during early spring when soil temperatures are still cool and microbial release of labile soil nitrogen is low. When applied to bermudagrass, late-season nutrition can also be very effective at enhancing fall color retention and promoting early spring green-up.[8] However, fertilizer applications should not take place during the winter months, because the environmental risks associated with nutrient loss are greatest during winter and very early spring when dormant turf is not actively growing. Heavy winter rains can leach nutrients from the soil or carry fertilizer away in surface runoff prior to plant uptake. Consider the environment and the Long-Term Diet for your course when making late-season fertility decisions. The best results from late-season fertilization will be achieved by applying a soluble fertilizer early enough in the season that the plants are still photosynthesizing and absorbing nutrients.

ECONOMICS OF FERTILIZATION — GETTING BACK TO BASICS

Fertilizer programs should be based on soil test data, observations of turf performance, playability, and economics. Performing a cost analysis on various fertilizer sources and products helps managers understand the economic impact of different products and identify forms of fertilizer that offer the greatest return on investment.

Fertilizer Budget — Cost per acre. Fertilizer comes in many different formulations, blends, and price ranges, but Does the Grass Know the Cost? The answer is no. All nutrients enter grass plants in an inorganic form. It is important to remember that nitrogen controls turfgrass growth more than any other macronutrient. When purchasing nitrogen fertilizer it is important to calculate the cost per pound or cost per acre of actual nitrogen. The product with the lowest cost per acre will be the most economical choice. Soluble elemental fertilizers are among the most economical and can be applied in granular form and watered in or sprayed in solution at low rates — i.e., less than 0.5 pound of actual nitrogen per 1,000 square feet — to enhance plant growth while preventing runoff and leaching. Affordability and precision are among The Benefits of Liquid Fertilization on Fairways, but labor and equipment availability may limit the frequency at which liquid products can be applied to large acreages.

Maximize Efficiency. Fertilizer nitrogen use efficiency (FNUE) refers to the ability of turf to uptake and

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Table 1
FERTILIZER SOURCES
Urea remains the least-expensive form of fertilizer and often is the derivative for a wide range of fertilizer products
FERTILIZER COST ANALYSIS

Fertilizer (50-pound bag unless noted)	Analysis	Approximate Cost	Pounds of Nitrogen per Container	Cost per One Pound of Nitrogen	Approximate Cost per Acre
Granular Applications (Assumes rate of 0.5 lb. N/1,000 sq. ft.)					
Urea	46-0-0	$18.00	23.0	$0.78	$17.05
Ammonium Sulfate	21-0-0	$15.00	10.5	$1.43	$31.11
Calcium Nitrate	15.5-0-0	$17.00	7.8	$2.19	$47.78
Complete Fertilizer	18-3-8	$20.00	9.0	$2.22	$48.40
Polymer-Coated Urea	41.5-0-0	$46.00	20.8	$2.22	$48.28
Organic Fertilizer	7-1-0	$18.00	3.5	$5.14	$112.01
Liquid Applications (Assumes rate of 0.15 lb. N/1,000 sq. ft.)					
Urea	46-0-0	$18.00	23.0	$0.78	$5.11
Ammonium Sulfate	21-0-0	$15.00	10.5	$1.43	$9.33
Calcium Nitrate	15.5-0-0	$17.00	7.8	$2.19	$14.33
Soluble Fertilizer (25 lbs.)	17-4-10	$30.00	4.3	$7.06	$46.12
Stabilized N Liquid Fertilizer (2.5 gal.)	19-2-4	$45.00	4.9	$9.20	$60.10
Liquid Fertilizer Product (2.5 gal.)	19-2-3	$100.00	5.2	$19.40	$126.76

metabolize liquid or granular nitrogen applied as fertilizer. FNUE for foliar products can range from 37 to 59 percent on bentgrass and 45 to 50 percent on ultradwarf bermudagrass.[9] However, FNUE is lower for granular products used on fertile soils because fertilizer efficiency decreases as the soil and microbes supply greater amounts of nitrogen to the plant. Urease and/or nitrification inhibitors common in stabilized nitrogen fertilizers aim at improving FNUE and may help prevent nitrogen losses under certain environmental conditions — i.e., heavy rain, high pH, or course-textured soil.[10] However, Optimization of foliar nitrogen to improve turf performance can be achieved by allowing four to six hours of drying time after application, utilizing lower spray volumes (i.e., less than 20 gallons per acre), and adding an adjuvant to the spray solution.

MYTH BUSTING

There are many theories about turfgrass fertilization and the benefits of various products, many of which have little basis in science. It is important to bust through the myths surrounding questionable products and practices by using science to justify fertility choices.

True or False? The soil can supply most of the nutrients. This is absolutely true. Nutrient uptake comes mainly from the soil. Golf course soils with a moderate to high cation exchange capacity, as described in Soil Fertility and Turfgrass Nutrition 101, will have the natural ability to provide more food — i.e., cationic nutrients — for plant uptake.

True/False? Calcium applications are needed to flocculate the soil. This is false. In the absence of high sodium, calcium additions in the field can do little to remedy soil structural and textural issues associated with compaction or high clay content. Most soils already have a large supply of calcium; therefore, additional calcium can only offer minimal benefits and could cause nutritional imbalances. However, Gypsum and Other Calcium Sources can help remedy low soil pH or high levels of harmful sodium. It is important to note that calcium additions to sand-based putting greens, where clay content is very low, will not improve soil water movement (Sand Greens and Sodium).

Organic Fertilizer – Can you manage turf solely with organics? Several excellent case studies exist in the golf industry, ranging from Vermicomposting Food Scraps to The Use of Organic Compost Products, that provide a baseline for answering the question Is Inorganic or Organic In? Incorporating some organic forms of fertilizer can help build microbial populations, assist with human and animal byproduct recycling, and lower golf's dependence on nonrenewable energy. However, the economic expense of going strictly "organic" often prohibits widespread adoption. Furthermore, there is potential for leachates high in phosphorus and potassium resulting from the use of some organic fertilizers, offsetting some of the potential environmental benefits.

True or False? Acidifying fertilizers do little to reduce soil pH. This is false. While soil pH is strongly buffered and not quickly changed in many soils, superintendents may be able to move the needle toward neutral

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pH over time. For example, ammonium-based nitrogen fertilizers are inherently acidic as the nitrification of ammonium releases hydrogen ions during the microbial oxidation process. When used extensively in fertility programs, ammonium-based fertilizers can help lower pH levels from mildly alkaline to near neutral. Additionally, when a product like ammonium sulfate is applied as a foliar spray, it can help reduce algae growth on bentgrass putting greens and reduce the infection potential of fungus in the rhizosphere.

Regular phosphorus applications are necessary for healthy turf growth. As outlined in the MLSN guidelines, when soil phosphorus levels meet or exceed 21 ppm, there is no need for regular phosphorus applications. Rules and regulations regarding the use of phosphorus are popping up around the country in places like Florida, Minnesota, Wisconsin, New Jersey, New York, and Massachusetts. While applying phosphorus is necessary during turfgrass establishment, the risks of Phosphorus Leaching from Sand-based Putting Greens can be minimized by making applications in smaller amounts at more frequent intervals. In general, best management practices, proper staff training, and strict utilization of soil and tissue tests can provide the foundation to prevent phosphorus runoff or leaching and help protect surface waters.

CONCLUSION

Applying fertilizer is a basic practice common to all golf courses. Golf course superintendents can operate more economically and with greater environmental sustainability by using only the amount of fertilizer required to sustain healthy playing surfaces. Golf course playability must be considered when creating an effective fertility program. Proper soil testing and the careful interpretation of soil test data are critical first steps when developing an economically and environmentally sustainable fertilizer program. Also, with the availability of many different fertilizers and formulations, it is important to perform cost analysis to identify areas where savings can be achieved without negatively affecting playability. Fertilizer is an important tool for boosting turfgrass performance and the judicious use of this resource will help golf courses remain economically and environmentally sustainable.

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Source selection plays a key role in the cost and functionality of fertilizers. Soluble fertilizers can be spread in granular form or sprayed as a liquid. Homogenous fertilizers dissolve quickly in the presence of water and can be applied in a granular form to closely mown turf areas. Complete fertilizers (lower right) are useful when multiple nutrient inputs are needed.

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GPS-guided spraying devices allow precise application of liquid nutrients on playing surfaces such as greens, tees, and fairways. This eliminates unwanted overspray and skipping, helping optimize resource use.

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