



THERE'S A TEST FOR THAT

▲ Author Sam Ferro busy at work in his lab in Linwood, KS.

Testing of soil, turf, and irrigation water now plays a very important part in building and maintaining quality fields. A variety of laboratories with expertise in various disciplines specialize in sports turf testing and are eager to assist the sports turf manager. Whether it's routine soil fertility management, disease diagnostics, drainage evaluations, or one of the many other issues that affect turf managers, there is a test for that. This article is intended to provide a brief introduction to

some of the tests that are available and information on how they may aid in providing successful fields.

NEW FIELD CONSTRUCTION

Sand-based athletic fields typically require soils and drainage to be brought in from off-site to construct the field. Before any soils are used for construction, they must be tested to determine compliance with project specifications or goals. The laboratory may also prepare trial blends of the sands, soils, and/or amendments in efforts to assess and optimize performance of the rootzone materials. Quality control testing is performed during construction to ensure quality consistent materials are used.

Drainage gravel should be tested for both natural and synthetic turf construction. For natural turf, gravel is assessed for performance and compatibility

» Important factors to evaluate

are sodium content, carbonate and bicarbonate content, total dissolved solids, and chloride amongst other analytes. These parameters can affect soil and turf quality, as well as the irrigation system.

with the rootzone. Synthetic turf gravel should be tested for drainage and stability.

Typical construction related laboratory tests include particle size analysis, mix ratio testing, infiltration rate testing (also known as percolation or permeability), and soil porosity evaluations.

ROUTINE MAINTENANCE

Soil nutrient testing should be part of every athletic field manager's tool bag. Macro-nutrient and trace element testing allows the turf manager to monitor current conditions and determine a baseline for their fields. This testing also provides a check of the effectiveness of fertilizers and soil amendments, and it offers the ability to adjust products and fine-tune applications based on science.

Samples should be sent to labs that specialize in turf testing. These labs will provide test results along with interpretative guidelines to aid in understanding

the data. Recommended testing intervals vary depending on intensity of management. Low input fields may only need testing every 2-3 years, while higher input fields benefit from annual testing.

Plant tissue analysis offers a snapshot of the nutritional status of the turf at the time the sample was taken. It provides information on the relative health of the turfgrass and interrelationships between all essential plant nutrients. Managers can determine if a specific nutrient is lacking before symptoms appear. When tissue testing is used in conjunction with a soil analysis, it can provide information on critical nutrient levels and how best to correct problems.

Irrigation water quality can be an important issue for sports turf managers. This is especially true for those who are using recycled water or gray water to irrigate fields. Important factors to evaluate are sodium content, carbonate and bicarbonate content, total dissolved solids, and chloride amongst other analytes. These parameters can affect soil and turf quality, as well as the irrigation system. Testing to monitor irrigation water quality can help prevent problems from arising with turf and equipment.

Many turf managers don't realize that topdress materials should be evaluated before use. Layering can occur if too fine of a topdress is used over the existing soil. When a finer soil layer builds up over an underlying coarser layer, there is a tendency for excess water to be held in the upper layer. This can lead to increases in disease pressures, shallow rooting, black layer formation, or excess surface compaction. A simple particle size test can determine topdress/rootzone compatibility and limit the potential for layering.

Testing of baseball/softball skin areas can help to pinpoint mix needs before purchasing sand, clays or amendments. Skin test results can be compared to industry standards for guidance regarding maintenance needs. Multi-field managers can use test results to aid in creating consistent performance throughout the complex.

Routine testing of synthetic turf? Yes, even artificial fields can benefit from analytical services. The consumer products safety commission and leading industry groups recommend biennial (every other year) Gmax testing for synthetic turf fields. In addition to Gmax analysis, synthetic field evaluations should include height of fibers, infill depth, inlay and seam analysis. This data supplies the information needed to show whether fields are in compliance with industry standards, pinpoints problem areas and provides recommendations for remedying trouble spots.

PROBLEM DIAGNOSTICS

It is extremely important to diagnose and eliminate turf problems before they become major issues.

Turf growth problems are often a result of improper nutrient levels. Soil and plant nutrient evaluations can provide guidance to correct and optimize growing conditions.

Many turfgrass diseases and problems look quite similar, making

visual diagnosis difficult. For an accurate diagnosis, samples can be sent to a turf pathologist. These scientists evaluate turf samples for pathogen signs and disease symptoms, identify problems, and make recommendations regarding management of the problem.

Every field has some pathogenic nematodes feeding on the plant roots. Many nematodes are harmless to plants, but others can cause damage. Nematode testing can indicate which nematodes are present, whether they are harmful, and provide guidance regarding control of pathogenic species.

Diagnostic profile core testing provides the ability to peer down below the surface of the field, and to see how the rootzone and drainage are working (or why they are not working). Intact subsurface soil samples (usually 6 to 16 inches deep) are broken down and evaluated at various depths throughout the soil profile. This allows for in depth portrayal of soil composition, soil layering, water holding and drainage characteristics. By providing detail on current soil conditions, profile core reports are especially beneficial when making field renovation decisions.



SAMPLING

The test results generated by the lab are only as good as the samples submitted for testing. If samples do not properly represent the field, then test results may lead to incorrect conclusions and recommendations that not only do not help but may

harm the field. Thus it is crucial that proper sampling techniques are performed. Different tests may require varying sampling and sample shipment requirements. If you are unsure of appropriate sampling techniques contact the testing lab for instructions.

As you can see, there is indeed a test or tests available to prevent, diagnose, and/or treat a multitude of field conditions. Most laboratories have personnel that are ready to discuss your particular situation before testing, and they are also ready to help you interpret and understand test results. Make testing a part of your turf management program, and you will see a positive impact on the appearance, playability, longevity and profitability of your sports fields. ■

Sam Ferro is president of Turf Diagnostics & Design, a leading physical testing laboratory serving the sportsturf, golf, and landscape markets.



ORGANIC MANAGEMENT and other systems employed in maintaining turfgrass

▲ **Calendar-based** preventative and curative applications can provide very good turf quality; however, the lack of site specificity can result in poorly timed and/or unnecessary fertilizer and pesticide applications.

There is increased interest in turfgrass management strategies that are intended to reduce or eliminate synthetic pesticides and, in some cases, synthetic fertilizers. Consumers' desire for organic food and its perceived benefits has translated into a growing demand for turf products and contracted services described as 'organic' or 'synthetic pesticide free'.

While the mischaracterization of a turfgrass management program may be entirely unintentional, marketing non-organic products or services as organic has numerous consequences, most obvious the customer not receiving what is being sold. In some cases, where synthetic pesticide free programs or organic management have been deemed 'successful,' these successes have served as a rationale to legislatively prohibit synthetic pesticide use. These 'successful' programs may have, in actuality, incorporated synthetic fertilizer and synthetic pesticide applications at some recent juncture, requiring a more accurate description of the programs, albeit a description less marketable than 'organic.'

The objective of this article is to describe the following turfgrass management philosophies to better enable

sports fields and grounds managers to sort-out common terminology used in the marketplace today: calendar-based preventative and curative applications; Integrated Pest Management (IPM); management without synthetic pesticides; and organic management.

For the purpose of clarity in this article, the term 'synthetic pesticide' includes products that meet each of the following criteria: 1) The product has a United States Environmental Protection Agency (EPA) pesticide registration number; and 2) The product is **not** approved for organic production per United States Department of Agriculture (USDA) National Organic Program (NOP) or Organic Materials Review Institute (OMRI) guidelines.

CALENDAR-BASED PREVENTATIVE & CURATIVE APPLICATIONS

Schools and municipalities are contracting-out pesticide and fertilizer applications at a more frequent rate. The lack of trained and licensed personnel, limited availability of application equipment, and other issues related to product storage have created a strong demand for contracted applications. Calendar-based preventative

and curative application programs that have traditionally served the home lawn market are often employed in the management of public sports fields and grounds due, in large part, to the fact that they can be readily integrated into the public bid process.

Contractor-submitted bids are typically based on a scheduled application of fertilizer and pesticide products on a specified date (or range of dates), to a known acreage, and at label-derived rates. Realistically, calendar-based contracted programs may be the only avenue in which fertilizers and pesticides are ever applied to sports fields and grounds in a public setting. However, the environmental suitability of these applications is often called into question as one-size-fits all protocols can result in pesticide and fertilizer applications that are poorly timed and/or unnecessary.

INTEGRATED PEST MANAGEMENT (IPM)

While numerous definitions have been authored to describe IPM, no conventional definition addresses fertilizer selection nor entails the elimination of synthetic pesticide use. The following is a definition developed by the Rutgers Pest Management Office: *As a long-term approach to maintaining healthy landscapes and facilities that reduces the risk to people and the environment, instead of routine chemical applications, IPM employs site assessment and monitoring, and pest management tactics that include horticultural, mechanical, physical, and biological controls and selective use of pesticides when needed to keep pests within acceptable limits.*

Site assessment and setting pest thresholds (i.e. acceptable limits) are IPM principles that can be used to reduce the quantity of pesticides applied to sports fields and grounds. Town properties and school district sports fields and grounds can be subdivided into zones (e.g. A, B, and

C) based on turf function and aesthetic priority. Pest threshold levels can then be established for individual zones.

For example, a school district may classify certain sports fields and lawns as Zone A turf locations on the basis that they have the highest expectations for function (playing surface quality) and aesthetics; thus, these locations have the lowest threshold level for weeds, diseases, and insect pests. Examples of Zone A turf areas may include varsity sports and practice fields used by high school athletes and high profile lawn and grounds locations.

Zone B sports fields and grounds may include turf locations where stakeholders have a moderate expectation level for playing surface and aesthetic quality such as sports fields used by middle school athletes, passive recreation areas, and lower visibility lawns. A greater level of weeds, diseases, and insect activity can be tolerated given the less intense recreational activity, younger age of athletes, and/or lower aesthetic importance.

Sports fields and grounds designated as Zone C can be determined to have the greatest threshold for pest activity and may include sports fields used by elementary school students, 'alternate fields' that are always open to users when high value fields are closed, and turf locations where soil stabilization (no wind or soil erosion) is the primary function of these grounds.

MANAGEMENT WITHOUT SYNTHETIC PESTICIDES

Laws essentially prohibiting the use of synthetic pesticides on school sports fields have been implemented in the State of New York (playgrounds, turf, athletic or playing fields at day care centers and schools [kindergarten through grade 12]) and Connecticut (grounds

▼ **Left:** As part of an Integrated Pest Management (IPM) plan, middle school sports fields may be deemed to have a higher threshold level for broadleaf weed populations compared to high school varsity fields. **Right:** Failure to develop any pest management plan resulted in nearly complete white grub damage of this municipal baseball outfield during late September.



of day care centers, elementary and middle schools [grade 8 and lower]). Additionally, at the time of the authoring of this article, a bill has been introduced in the New Jersey State Legislature prohibiting 'lawn care pesticide' use on the grounds of day care centers, schools, and sports fields at municipal, county and state park facilities. The proposed New Jersey Safe Playing Fields Act defines a 'lawn care pesticide' as "... any pesticide labeled, designed or intended for use on lawn, gardens, turf or ornamental plants". These laws and proposed bill provide allowances for 'emergency' pesticide applications per approval from varying authorities.

It is important to note that these laws and bill do not address fertilizer use; thus, it is a mischaracterization to state that organic management is being legislatively mandated in these cases.

The New York and Connecticut laws and proposed New Jersey legislation allow the application of Minimum Risk Pesticides. These products contain active ingredients that are exempt under Section 25b of the Federal Insecticide Fungicide Rodenticide Act (FIFRA) and do not require EPA registration (i.e. they do not require an EPA registration number) because the EPA considers their ingredients, both active and inert, demonstrably safe for the intended use. (www.epa.gov/oppbopd1/biopesticides/regtools/25b_list.htm). Examples of minimum risk active ingredients included in products marketed for use in turf include, but may not be limited to: cedar oil, citric acid, clove oil, corn gluten meal, eugenol (oil of cloves), lauryl sulfate (sodium lauryl sulfate), 2-phenethyl propionate (2-phenylethyl propionate), sodium chloride (common salt), and sodium lauryl sulfate.

It is extremely important to understand the specifics of the laws under which one is governed. For example, pesticide products that

have an EPA registration number are not allowed for use on the grounds of day care centers and elementary and middle schools in Connecticut, regardless of whether or not the product is approved for use in organic production (e.g. Avenger Weed Killer; OMRI-listed; EPA Reg. No. 82052-1; and M-Pede; OMRI-listed; EPA Reg. No. 62719-515).

A thorough evaluation of the success of a management program that excludes synthetic pesticides must take into consideration prior management history. Sports fields and grounds where synthetic herbicides and insecticides have been routinely applied typically have few weed and insect problems. Initiating a program (and maintaining acceptable turf quality) without synthetic pesticides on properties with minimal weed and insect problems presents less of a challenge compared to beginning such a program on turf riddled with annual and perennial weeds and/or insect pests.

ORGANIC MANAGEMENT

The USDA NOP defines 'organic' as a labeling term that indicates that the food or other agricultural product has been produced through approved methods that integrate cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity (www.ams.usda.gov/AMSv1.0/nop). Materials allowed for use in organic production are either essentially derived from living things or naturally occurring minerals.

The USDA NOP definition underscores that organic management, to this point, has been employed primarily in agricultural production systems, as opposed to turfgrass and

▼ **Left:** Within a school district, the greatest broadleaf weed population can often be tolerated on the sports fields and grounds surrounding elementary schools. **Right:** This suburban New Jersey sports field has not received a synthetic pesticide application since 2009 (photo taken October 2013). Before this program, synthetic pesticides were routinely applied to the sports field which consisted of good turfgrass cover. Current cultural practices promote competitive turfgrass: regular mowing (3 inches), fertilization, aerification, and overseeding.



landscapes. The USDA NOP was developed to create standards for organic farming and administer organic certification – which verifies that a farm or handling facility complies with the USDA organic regulations and allow the sale, labeling, and representation of a product(s) described as organic.

To meet USDA NOP certification requirements for crop production, organic farmers are prohibited from applying non-conforming substances to the land for three years before the harvest of an organic crop. This requirement, albeit rigorous, preserves the integrity of products labeled organic and drastically contrasts with a recent effort to develop standards for organic land care (including lawns) that allows applications of non-organic materials under an ‘Emergency Non-Organic Rescue Treatment’ provision. The standards, developed by Northeast Organic Farming Association (NOFA), emphasize that emergency non-organic rescue treatments must be rare, must only be undertaken as a last resort, and must be approved by the client (www.organiclandcare.net/accreditation/standards). Where a pest population exceeds a pre-established threshold (established by the turf manager and/or client) and a synthetic pesticide is used reduce the pest population to an acceptable limit, the management system should be characterized as IPM.

In its broadest sense, organic turf management seeks to apply the principles of organic crop management to the maintenance of turfgrasses. A primary tenant of organic management is the emphasis on systems-based management as opposed to product-focused management. Synthetic pesticides and fertilizers are commonly applied using a calendar-based approach; organic-conforming products can be applied in a similar manner by simply removing the synthetic product from a calendar program and inserting an organic product. Organic philosophy discourages this type of simple input substitution as it is inconsistent with broader systems-based models that emphasize soil preparation, proper establishment methods, turfgrass selection, and cultural practices that favor healthy, competitive turfgrass.

Per USDA NOP guidelines, synthetic fertilizers, sewage sludge, irradiation, and genetic engineering may not be used in organic agricultural systems. “Materials for Organic Crop Production” (NOP 5034-1), currently in Draft Guidance form, lists materials (including some synthetic) that comply with USDA organic regulations (www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5103311). Additionally, Organic Materials Review Institute (OMRI) is a nonprofit organization that provides organic certifiers, growers, manufacturers, and suppliers an independent review of products intended for use in certified organic production, handling, and processing (www.omri.org). The OMRI Products List is a directory of all products OMRI has determined are allowed for use in organic production, processing, and handling according to the USDA National Organic Program.

To preserve the integrity of an organic turf program, turfgrass managers should confine their product choices to those that are OMRI-listed or can be found on the “Materials for Organic Crop Production” list. All too often, confusion arises over what materials are allowable as part of organic management. Restricting product use to those products that appear on OMRI and USDA NOP lists provides a level of validation that the system is being managed in a manner that can legitimately be characterized as organic.

An example of non-organic materials readily mischaracterized as organic involves ‘organic-based’ fertilizers. These fertilizers will often contain one or more natural organic fertilizer sources (e.g. bone meal, blood meal, feather meal, etc.) allowable in organic production but also contain synthetic nitrogen (N) sources and/or biosolids. Synthetic N sources and biosolids are prohibited for use in organic production; thus, when these materials are applied to turfgrass, the management system should not be characterized as organic.

Because there is no national organic program for turf management, the validity and integrity of an organic program is the responsibility of the turf manager, whether the manager is directly employed by the property owner (i.e. school or town) or working as a contractor.

CONCLUSIONS

The underpinnings of successful IPM, synthetic pesticide free, and organic turf management programs include sound agronomic decision making, as opposed to simply figuring out what products can be applied and when (including Minimum Risk Pesticide, organic-approved products, etc.). Examples of systems-based management include utilizing construction methods that preserve topsoil quality and if necessary amending soils with compost to improve soil organic matter; timely establishment and selection of the best adapted turfgrass species and varieties that have demonstrated lower disease and insect susceptibility; and properly executing all cultural practices including raising mowing heights to encourage more competitive turf and returning clippings to recycle nutrients. Systems-based management strategies for sports fields include the aforementioned in addition to frequent cultivation to alleviate soil compaction on native soil fields; aggressive overseeding to account for voids in the turf cover caused by traffic; supplying ample fertilization to ensure active turf growth and recovery; and using growth blankets to promote seed germination and turfgrass growth when soil and air temperatures discourage turfgrass physiological activity. ■

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SOIL DYNAMICS and effective irrigation management

Over the past year, I have had the opportunity to become involved in the day to day management of an irrigation system installed 3 years before a newly reconstructed sports complex. I must admit that since becoming a sports field manager 25 years ago, I have never had the opportunity to become so intimately involved in irrigation management. However, on this particular field, problems had arisen which required serious consideration of all the facets of the turf management program.

Conceptually, irrigation management is simple. Just replace the water lost to evapotranspiration; the combined effects of soil evaporation and moisture loss thru turf transpiration. I was told by one employee that the previous year he had gotten daily evapotranspiration data from a local weather-related website. A basic understanding of his irrigation system allowed him the ability to use this information and program the system to apply what was required.

As I ran through the different irrigation zones on the field, I noticed

some heads were not rotating, others were puddling and still others were watering in the wrong direction. Irrigation heads within the same zone were randomly fitted with different size nozzles. An irrigation audit completed by a certified irrigation auditor later reported that the system was only about 60% efficient.

Examination of the soil profile revealed major differences in soil compaction. In some areas of the field I could insert a soil probe 7 or 8 inches, in other areas only two or three. By coincidence, areas of sod replaced the year before due to fungus, coincided with these areas of heavier compaction. The areas of heavy compaction were programmed to receive the same amount of water as areas with much less compaction. Poor drainage in the heavily compacted areas was causing standing water to accumulate after irrigation. I can only assume that wet feet coupled with restricted root development had some bearing on sod loss.

In an attempt to optimize the effectiveness of the irrigation, I purchased a soil moisture meter. I did this intent on gaining a better

understanding of the moisture needs of the turf. Initial readings revealed differences in soil moisture which at the time seemed counterintuitive. Areas of the field with minimal compaction showed moisture content to be around 25%. Areas of high compaction with visual signs of standing water and obvious saturation showed soil moisture content only to be around 18%. I am not the sharpest tool in the shed and came to the conclusion that these moisture readings, alone, meant absolutely nothing to me and I would need more information. I continued to take readings hoping an epiphany would suddenly make it all clear to me. It instead became clear that my efforts were in vain.

As I began to research a little deeper, it started to make sense that in order to competently program irrigation based on evapotranspiration data; it would first require a baseline soil moisture measurement or irrigation threshold. This irrigation threshold would be used as a reference point from which to determine the need for supplemental irrigation. To better understand this concept it becomes important to have a basic understanding of soil. The following information helped to clarify my confusion.

Soil is typically a mixture of inorganic and organic particles. The inorganic particles are mineral based and come from rocks that have been weathered and broken down into smaller pieces over a long period of time. The organic particles contain carbon compounds and they come from anything that was once living and has since died and decayed, including plants, microbes, insects and animals.

Soil texture is determined by the relative amounts of sand, silt and clay.

Soil structure refers to the arrangement of the sand, silt and clay particles joined together into larger aggregates of different sizes and shapes and the pore spaces that are left between them. It is in these spaces that root hairs grow and take in water and nutrients from the soil.

In heavier textured soils, soil structure favorable to turf growth is one that has stable aggregates. These aggregates result in a network of both small and large soil pores that has good aeration and drainage and allows for efficient exchange of air, water and nutrients. In sandy soils, typically having more than 85% sand, adequate pore space is primarily a product of particle size rather than soil aggregation.

The processes of root penetration, wetting and drying cycles, freezing and thawing, and microbial activity combined with inorganic and organic cementing agents produce soil structure. Soil structure can be severely compromised in many ways such as by compaction, playing on a field when it is too wet or by over tilling during construction or repairs.

After rain or irrigation, the pore space in soil typically fills with water. **Saturation** occurs when all the pores are full of water and the soil can hold no more water. This is the time when playing surfaces are generally most unstable and most vulnerable to damage caused by traffic. As moisture drains from the soil, the soil will typically become more stable. For this reason, it makes sense for the turf manager to manage soil moisture at a level favorable to turf survival yet providing a root zone stable enough to resistant damage by traffic.

Not all of the water will drain due to gravity. Some water will stay in the soil. Moisture will remain in the smaller pore spaces and as a thin coating on the outside of the soil particles. This remaining moisture held

in the soil against the force of gravity is known as **capillary moisture**.

After the gravitational water has drained away, the soil is said to be at **field capacity**. At field capacity water in the pores is typically easy for the plant roots to use. Once the pore water is used up, there is normally a thin coating of moisture remaining around the soil particles. The **permanent wilting point** is defined as the point at which remaining soil moisture is held so tightly that it is unavailable to plants. Plants subjected to this level of soil moisture will not typically recover. Turf will usually exhibit signs of drought stress before the soil reaches the permanent wilting point. The amount of water held in the soil between field capacity and the permanent wilting point is called the **plant available water**. A sandy soil will typically hold less water at field capacity than a heavy textured clay soil but a larger percentage of that water is plant available water.

There are two means of identifying soil moisture content in the field. Volumetric soil moisture is measured as a percentage of the total soil volume. Soil moisture tension is a measure of how tightly water is held in the soil.

Volumetric soil moisture is a method of measurement used by many moisture meters to measure moisture in the soil and can be used as a means of monitoring irrigation requirements. Each location should be evaluated individually and the volumetric soil moisture compared to turf quality and soil conditions at the time the reading is taken. The



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accumulation of volumetric soil moisture data for a given location, over time, can give the turf manager the ability to correlate soil moisture readings, predict turf needs and irrigate accordingly.

Soil moisture tension is a phenomenon caused by the capillarity of water. **Capillarity** is the combined effect of cohesion and adhesion. **Cohesion** is the attraction water has to itself. It is the reason water beads up on a sheet of glass. **Adhesion** is the attraction water has to another surface; in this case it is the attraction to the soil particles. Moisture adhesion to the soil is typically the stronger of these two properties. Capillarity causes some water to remain in the soil after gravitational water has drained away. Capillarity also allows for water movement thru the turf plant against the force of gravity. This movement of water against the force of gravity is called **capillary motion**. Soil moisture tension increases as the volume of soil moisture decreases. Soil moisture tension can increase to a point where moisture remaining in the soil is held so strongly, it is unavailable to the turf. This is the permanent wilting point as previously described.

Kilopascals (kPa) are units of pressure measurement used to measure soil moisture tension. Suction is a negative pressure or tension and is therefore referred to by negative numbers. Soil moisture tension is a measure of suction, and the correct way to refer to it is minus or negative X kPa. Numbers closer to zero refer to less suction and therefore wetter soils. As a soil dries out the kPa value becomes larger (and more negative).

One benefit to measuring soil moisture tension as opposed to volumetric soil moisture is that soil texture is largely irrelevant. -25kPa in clay is the same as -25kPa in sand. Turf in either of these soils is basically working the same to extract moisture.

A **tensiometer** is a hand-held device that is forced into the ground for the purpose of measuring soil moisture tension. The hollow ceramic tip of a tensiometer is porous, allowing water to move into and out of a sealed water storage 'reservoir' or tube inside the tensiometer shaft. As the soil dries out, water is sucked out of the tensiometer through the porous ceramic tip. This creates a partial vacuum inside of the tube, which is registered by a vacuum gauge. Tensiometers usually operate accurately over a range of 0 kPa to -80kPa. **Gypsum block** sensors are also available for measuring soil moisture tension and can be buried in different locations of a field to allow for soil moisture tension measurements. Gypsum is a naturally occurring porous mineral. When shaped into a block and buried in the soil, water from the surrounding soil moves into and out of the gypsum block as though it were soil.

A gypsum block sensor consists of two electrodes embedded in a block, 'tablet' or cylinder of gypsum. When water moves into the gypsum block some of that gypsum dissolves, allowing a current to move between the electrodes. As the amount of water in the block changes so does the resistance to current flow.

As the soil dries out, water leaves the gypsum block and the resistance between the electrodes increases. Conversely, as the soil wets, soil water is drawn back into the gypsum block and the resistance decreases. These resistance values are then translated into soil moisture tension readings by a meter connected to the two electrodes, which displays the soil moisture tension as units of kilopascals (kPa).

The level of soil moisture tension required to sustain turf can vary by turfgrass species, region of the country and other environmental factors.

-50kPa to -80kPa may represent an approximate irrigation threshold for cool season turf above which the sports field manager could anticipate draught stress and a decline in turf quality. As always, it is the responsibility of the sports field manager to evaluate soil moisture tension readings as they compare to turf quality and use good judgment when establishing an irrigation threshold from which to initiate irrigation.

Dielectric Constant or Dielectric Permittivity Sensors use electric fields to monitor a dynamic of soil called its 'dielectric constant'. Water greatly changes a soil's dielectric constant. Dry soil has a dielectric constant of between 2 and 5. Pure water has a dielectric constant of 80. Consequently, as the moisture level in the soil changes, the dielectric constant changes accordingly.

This class of sensors uses the dielectric permittivity as a means of reporting soil moisture content. A key advantage of these sensors is that mineral particles such as salt barely affect the dielectric constant of soil so the soil moisture readings are largely unaffected.

Although each employs a different technology, thetaprobes, capacitance or frequency domain reflectometry (FDR) probes and time domain reflectometry (TDR) devices all rely on the dielectric permittivity of soil for their soil moisture measurements.

In addition to soil moisture monitoring being available as a manual method of establishing and maintaining an irrigation threshold, manufacturers of automated irrigation systems have integrated similar methods of soil moisture monitoring as means of controlling supplemental irrigation. Whether you choose to monitor soil moisture yourself or incorporate it into an automated irrigation system, your choice becomes another tool in your sports field manager's tool box.

The methods of monitoring soil moisture mentioned in this article should not be considered the only options available to the sports field manager. This article is intended only to suggest the benefits that can be realized through soil moisture monitoring and the tools mentioned are used only as examples to help better understand the principles provided.

In the past 25 years, I have attended many classes and read a lot of books and articles on the topic of soil. However, I had not seriously considered the interrelationship between soil dynamics and effective irrigation management. The positive or negative influences that in sum total contribute to an improvement or decline in turf quality warrant understanding and consideration. Knowledge acquired thru success is far less expensive than wisdom acquired thru failure.

As for the field I mentioned at the beginning of the article; a basic review of these few principles concerning soil and soil moisture gave me the ability to comprehend why and how the compacted soil I had previously identified as having 18% moisture could conceivably measure less moisture, and exhibit a higher level of saturation than other areas of the field. We look forward to having the irrigation system repairs completed in the spring and hope to be able to establish an effective irrigation threshold from which to program the supplemental irrigation needs of the turf. We will also be working to further relieve compaction across the board. ■

Jim Hermann, CSFM, is President of Total Control Inc. Athletic Field Management.

NICKEL AND TURFGRASS GROWTH: ALL YOU NEED TO KNOW



▲ These two photos show reduced growth with increasing Ni treatments from Clemson's toxicity study. Each one shows four representative plots of either Diamond zoysiagrass or TifEagle bermudagrass under Control, 400, 800, and 1600 uM Ni treatments. The reduction in clipping yield is significant and easy to see.

Turfgrass managers are always trying to leverage acceptable conditions with minimal inputs (water, nutrients, and pesticides). Maintaining optimal plant nutrition is the foundation of sustaining healthy turfgrasses that require fewer inputs. Liebig's Law of the Minimum states that plant growth is controlled not by the total amount of resources (nutrients) available, but by the most scarce resource (limiting factor). Due to the fertilization of macro and most micronutrients, this principle isn't usually a problem. However, there are trace micronutrients that play critical roles in the plant that we should consider, such as nickel (Ni). Nickel constitutes approximately 3% of the earth's crust and is the 24th most abundant element. Nickel is a trace micronutrient that was discovered to be essential for plants in the 1980s. Typical ranges of Ni in soils range from 5-500 ppm; however, measuring bioavailability in soils is difficult because the plant available form Ni^{2+} readily oxidizes in the soil rendering it unavailable. Nickel is commonly forgotten in the world of turfgrass nutrition because of the low concentration found in plants (0.05-10 ppm) which is thought to be adequately provided by the soil. However, Liebig should not be disregarded when it comes to Ni and turfgrass.

NICKEL BIOAVAILABILITY

Sports turf grasses are commonly grown in conditions conducive to reduced bioavailability of Ni:

- Dry and/or cool soils in early spring, (Common throughout the Carolinas)
- Soil pH > 7, (Limestone based calcareous sands, which are commonly used for turfgrass root zones typically have pH values in the 8.2 range)
- Sandy and or low CEC soils (Putting greens, tees, and frequently top-dressed playing surfaces)

In addition, the following management factors influence Ni bioavailability:

- The presence of root-knot nematodes (*Meloidogyne* sp.) (Root-knot nematodes are not as damaging to turfgrass as sting or lance nematodes but are still commonly found in soils and can contribute to reduced Ni bioavailability)
- Exceedingly high concentrations of Zn, Cu, Mn, Fe, Ca, and Mg, (Rooney et al., 2007; Wood et al., 2006) (Many constructed root zones are derived from calcareous sands. Additionally, liming materials and other Ca sources (gypsum) are commonly applied in turfgrass management increasing Ca in the root zone)
- Ni deficiency was triggered in pecan with foliar applications of Fe, and heavy early spring application of N. (Turfgrass managers commonly fertilize with both of these nutrients to correct deficiencies and improve turf color.)

Ni TOXICITY, DEFICIENCY, HYPERACCUMULATION, AND PLANT DEFENSE

Minimal information exists on Ni toxicity and deficiency for turfgrasses. However, by way of other plant research, we can make some conclusions about Ni. One of the most well documented Ni deficiency cases has been in pecan trees, in which the deficiency caused a disruption in carbon metabolism resulting in stunted growth leaves termed "mouse ear." Foliar sprays of Ni corrected the deficiency, but only in newly emerged leaf tissue. The diagnosis and management has brought to surface the importance of Ni in plant health and suggests the possibility that many horticulture crops may possess a "hidden hunger" for Ni.

Plants found growing on serpentine soils containing elevated levels of metals (Zn, Cu, Co, Fe, Cr, Mg, and Ni) can hyperaccumulate Ni without deleterious effects. Nickel hyperaccumulator species have been studied for their potential in the phytoremediation of soils contami-

nated with metals by industrial processes. It is hypothesized that these hyperaccumulators evolved to exploit high soil Ni concentrations to enhance plant defenses from herbivory and disease.

NI NUTRITION AND UREA NITROGEN METABOLISM

Nickel is a highly mobile element in the plant due to chelation with organic molecules and tends to accumulate in newly formed tissue. Several enzymes in biological systems require Ni as a catalyst; however, the most well-known role of Ni in plant metabolism is its function in the activation of the enzyme urease. Urease hydrolyzes (breaks down) urea into ammonia and carbon dioxide. The hydrolysis of urea by the Ni dependent enzyme urease is necessary to make the nitrogen (N) in urea available to plants. Urease cannot work if it is not accompanied by Ni. Urea is the most popular N source in management due to its solubility, high percentage of N, low price, and ease of handling. Urease and Ni are also important for plants being fertilized with other N sources (nitrate and ammonium) because of the need to cycle urea generated as a byproduct of metabolic processes within the plant. Nickel deficiency has been recorded in several species and leads to an accumulation of urea in leaf tissue causing toxicity, foliar burn, and inefficient urea-N use. Research has determined that plants can directly absorb urea through urea specific channels and aquaporins (water channels found in cell membranes), which changes the previously hypothesized view that urea-N was absorbed by the plant only after being hydrolyzed by urease in the soil or plant surface. Soil urease inhibitors have been thoroughly researched and employed to limit gaseous N loss by ammonia volatilization after hydrolysis. However, the directly absorbed urea from leaf surfaces is directly hydrolyzed by urease in the plant tissue before being assimilated into organic N containing compounds.

Nickel nutrition

- Very little is known about Ni nutrition and fertilization of turfgrasses.
- Due to the extensive use of urea and the necessity of Ni in urea N metabolism, further research is required to determine best management practices for foliar urea N fertilization and supplemental Ni fertilization.
- Increased leaf tissue growth due to Ni supplementation was observed in 'Diamond' zoysiagrass and 'TifEagle' ultradwarf bermudagrass during research at Clemson University.
- Nickel is an essential plant micronutrient
- The reduced Ni bioavailability in common turfgrass management scenarios requires further research to determine Ni sufficiency and deficiency ranges
- Nickel is required for functional urease activity in plants
- Urease is a Ni dependent enzyme that hydrolyzes urea making the N available to plants
- Urease and Ni are important in the cycling of urea generated within the plant and can reduce urea toxicity (foliar burn)

CURRENT RESEARCH

Research conducted at Clemson University reported increases in urease activity, amino acid content, and growth of 'Diamond' zoysiagrass and 'TifEagle' bermudagrass fertilized with foliar urea and supplemental Ni. Plants not receiving supplemental Ni contained <1 ppm Ni in leaf tissue, whereas Ni supplemented plants accumulated up to 17 ppm by the conclusion of the study. At this concentration, no toxicity symptoms were observed. In a second study at Clemson University, Ni toxicity was examined in the same species. Symptoms of toxicity progressively increased as Ni concentration reached 100 ppm and resulted in growth reductions up to 32% in 'TifEagle' at the highest Ni concentration supplied. Due to these findings, 'Diamond' and 'TifEagle' are considered moderately tolerant of Ni and further research should be conducted to measure the effects of Ni supplementation and toxicity of other commonly used turf species.

FUTURE PROSPECTS

Not much is known about other roles Ni plays in the plant and current research is lacking in most agricultural crops including turfgrass. However, from the limited research already conducted, increases in growth and plant health with supplemental Ni nutrition have been recorded. Future research is required due to the popularity of urea as an N source in turfgrass management and strong relationship with the Ni containing enzyme urease that makes the N available to the plant. Further, several questions have been raised concerning Ni nutrition and turfgrass management: Can turf be established more quickly (seeding, sprigging) when supplemental Ni is applied? Are there synergistic effects with pesticides to reduce total inputs and improve plant health? What are the long-term ecological impacts of Ni supplementation? Can Ni supplementation improve urea N use efficiency and does it improve foliar uptake? Can increased Ni concentration in foliage inhibit herbivory? Is there enough Ni bioavailable for turfgrasses that supplementation is not necessary?

Currently, no Ni fertilizer sources are marketed for turfgrass, while other micronutrients with similar concentrations within the plant (Mo) are commonly included in liquid micronutrient products. Only one Ni fertilizer is currently marketed (Nickel Plus, Nipan LLC.) for use in pecan. To investigate Ni nutrition and possible turfgrass deficiency, an estimate of Ni input needs to be determined for managed turfgrass surfaces. Additional research determining bioavailability in turfgrass scenarios also needs to be conducted to examine if Ni supplementation would be beneficial. ■

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