soil test P (17), with greater effectiveness indicating more rapid change in soil test P per unit of fertilizer P applied (poorer buffering), and greater long term risk of P loss. The objective of this study was to determine how repeated N-based applications of organic fertilizer sources to established turfgrass affected soil test P and P saturation in native soil and a sand-based rootzone mixture under field conditions.

▼ **Table 2.** Annual nitrogen (N) and phosphorous (P_2O_5) application rates for soil and sand root zones.

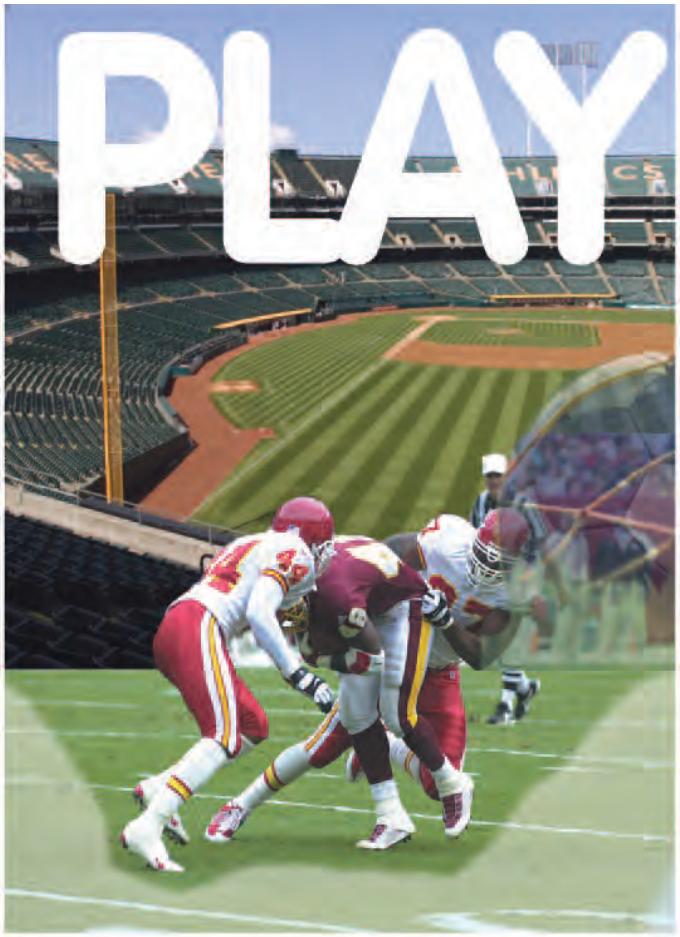
Fertilizer product	Soil	Sand	Soil	Sand
	kg N/ha/yr		kg P_2O_5/ha/yr	
Organic 8-3-5 1×	147	245	55	92
Organic 8-3-5 1.5×	221	368	83	138
Organic 6-7-0 1×	177	294	206	343
Organic 6-7-0 1.5×	265	441	309	515
PCSCU 20-5-10	147	245	37	61

FERTILIZER APPLICATIONS AND MEASUREMENTS

For this study, fertilizers were applied on an N basis, using natural organic and synthetic fertilizer sources on perennial ryegrass plots on two rootzone media over 3 years (July 2008-June 2011). Soil samples from the plots were analyzed to determine changes in P availability in each treatment area after three years of applications. Application rates of the fertilizers were based on their N content for the original experimental design; therefore, P levels were not equalized among treatments.

Perennial ryegrass was grown on both a Puyallup fine sandy loam native soil (coarse-loamy over sandy, isotic over mixed, mesic Fluventic Haploxerolls) and a USGA sand/peat 90/10% rootzone mixture in the Puyallup Valley of western Washington, south of Seattle. The plots on the native soil were maintained at 62.5 mm as a home lawn and the plots on the sand/peat mixture were maintained at 12.5 mm as a golf course fairway. All grass clippings were returned to the plots. The experimental design for each site was a randomized complete block with five fertilizer treatments and four replications. Plot size was 1.5 m by 3 m.

Each plot was fertilized with one of five treatments. The treatments included two natural organic fertilizer sources at a 1× and a 1.5 × N rate and a synthetic slow-release product at a 1× N rate. The target annual N



rate (1×) for the native soil plots was 147 kg/ha , consistent with recommendations for home lawns, while the target annual N rate (1×) for the sand/peat plots was 245 kg/ha, consistent with golf course fairway management. Fertilization was split into three equal applications per year on the native soil plots and five applications per year on the sand/peat plots. The 1.5× rate treatments received 50% more fertilizer on each application date.

The organic fertilizer sources were Organic 6-7-0, made from anaerobically digested and heat-dried municipal biosolids, and a commercially available Organic 8-3-5, made from mixed animal by-products. In the field, the Organic 6-7-0 N application rate was slightly higher than the Organic 8-3-5 rate. This was because the product was originally labeled as 5% N (5-4-0), but subsequent analysis showed it to be 6-7-0. Based on the fertilizers applied to each treatment on an N basis, the amount of P added per year in the organic fertilizers ranged from 55 to 138 kg P O /ha for the Organic 8-3-5 and from 206 to 515 kg/ha for the Organic 6-7-0. The synthetic slow-release control N source was a 20-5-10 formulation containing polymer-coated, sulfur-coated urea (PCSCU). The P in this formulation was monoammonium phosphate. It was applied at the same N rate as Organic 8-3-5. Phosphorus rates for this material were 37 kg P O /ha/year for native soil managed as home lawn and 61 kg/ha/year for sand managed as a golf course fairway.

For the native soil plots managed as a home lawn, fertilizer application dates were August and October 2008; May, June, and Oct 2009; April, August, and October 2010; and April 2011. For the sand-based plots managed as a golf course fairway, fertilizer application dates were August, October, and November 2008; April, June, July, September, and November 2009; March, May, August, September, and November 2010; and March and May of 2011.

In July of 2011, six to eight 25-mm-diameter soil cores were removed to a 100-mm soil depth from each plot. Unfertilized control samples were taken at the same time from untreated areas surrounding the plots. Verdure and thatch were discarded. Samples were mixed, placed in paper bags, moved to a greenhouse, and allowed to air dry for 1 week. After drying the samples, they were analyzed for Bray 1-P and ammonium oxalate extractable Fe, Al, and P. This data was used to determine phosphorus saturation (PSI) in each treatment in each soil type. We also compared the effectiveness of the P fertilizers in changing Bray-1 P, calculated as the slope of the linear regression of Bray-1 P vs. total fertilizer P applied. All data were analyzed using SAS PROC ANOVA, with means separation by least significant difference following a significant F-test.

Phosphorus saturation was calculated as: PSI = P / [Fe + Al], where P, Fe, and Al are the molar concentrations of oxalate-extractable phosphorus, iron, and aluminum in the soil.

A similar oxalate extraction and calculation was done on the two natural organic fertilizers to determine the relative degree of P binding with Fe and Al in each material.

PHOSPHORUS LEVELS AND POTENTIAL LOSSES

Values for Bray-1 extractable P were significantly higher in most of the Organic 6-7-0 treatments when compared to the PCSCU fertilizer treatment. In the native fine sandy loam soil managed as home lawn, the plots receiving Organic 6-7-0 1.5× treatments were significantly higher in extractable P than the PCSCU treatment, and in the sand-based fairway soil, both sets of plots receiving Organic 6-7-0 treatments were significantly higher in extractable P than the PCSCU treatment.

The plots receiving Organic 8-3-5 treatments showed a trend for higher Bray 1-P than the plots receiving synthetic fertilizer, but differ-

▼ **Table 3.** Bray 1-P saturation (PSI_{ox}) in the soil root zone after three years of fertilizer application, 2008-2011.

Fertilizer product	Soil Bray 1-P	Soil test level[a]	PSIox[b]
	mg/kg		
PCSCU 20-5-10	19.3 B[c]	low	0.13
Organic 8-3-5 1×	22.8 B	medium	0.12
Organic 8-3-5 1.5×	21.3 B	medium	0.13
Organic 6-7-0 1×	35.0 A	medium	0.13
Organic 6-7-0 1.5×	38.5 A	medium	0.14
LSD	6.8	–	NS

[a] Low = < 20 mg/kg; medium = 20-40 mg/kg; high = 40-100 mg/kg; excessive = >100 mg/kg. Horneck et al. (7).
[b] Phosphorous saturation index = P_{ox}/ [Fe_{ox} + Al_{ox}]
[c] Means followed by the same letter are notsignificantly different. $P = 0.05$. Mean of four samples. Control Soil Samples (untreated areas surrounding plots) Bray-1P Test = 18mg/kg.

▼ **Table 4.** Bray 1-P and P saturation (PSI_{ox}) in the sand root zone after three years of fertilizer application, 2008-2011.

Fertilizer product	Sand Bray 1-P	Soil Test Level	PSI_{ox}[a]
	mg/kg		
PCSCU 20-5-10	23.5 B[b]	medium	0.09 C
Organic 8-3-5 1×	27.3 B	medium	0.10 C
Organic 8-3-5 1.5×	28.0 B	medium	0.11 BC
Organic 6-7-0 1×	66.3 A	high	0.12 AB
Organic 6-7-0 1.5×	75.3 A	high	0.13 A
LSD	12.8	–	0.02

[a] Phosphorous saturation index = P_{ox}/ [Fe_{ox} + Al_{ox}]
[b] Means followed by the same letter are not significantly different. $P = 0.05$. Mean of four samples. Control Soil Samples (untreated areas surrounding plots) Bray-1P Test = 16mg/kg.

ences were not significantly different in either soil. Bray-1 test levels were in the low range in the pre-fertilization control soils and the PCSCU treatment in native soil, but were in the medium or high ranges following 3 years of application of natural organic fertilizers. In the Pacific Northwest, turfgrass shows little or no response to added P in soils that test in the medium or high range (> 20 mg P/kg soil).

To determine if the potential risk of soluble P loss had increased, oxalate extractions of Al, Fe, and P were run to determine if the fertilizer applications had affected P saturation (PSI) for each treatment and soil type. The results of these calculations showed no significant difference between PSI values for any of the fertilizer treatments on native soil after 3 years of fertilizer applications. However, on sand, both Organic 6-7-0 treatments had significantly higher PSI values than the other fertilizer treatments.

The change in Bray-1 P was much greater than the change in PSI, reflecting that the soils had exceeded the upper threshold for plant response to P, but had not yet reached a level of concern for soluble P loss. The PSI of the fertilizers alone was 16.6 for the Organic 8-3-5 compared with 3.8 for the Organic 6-7-0 biosolids product. The PSI of Organic 8-3-5 is similar to that of chicken manure (PSI = 15) as reported by Elliot et al., while the PSI for Organic 6-7-0 was higher than reported for a range of biosolids products (PSI = 0.47 to 1.4). The Organic 6-7-0 applications had a greater influence on Bray-1 P and soil PSI than the Organic 8-3-5, despite having a greater P binding capacity, because nearly four times as much P was applied in the Organic 6-7-0 than in Organic 8-3-5. Organic 6-7-0 applications added six to nine times as much P each year as the synthetic control, resulting in a large excess of applied P when products were applied to meet N needs.

We also calculated the relationship between the change in Bray-1 P applied for both natural organic fertilizers in both soils to compare the effectiveness of the fertilizers in raising soil test P. The change in Bray-1 P averaged 0.057 mg/kg for every kg/ha fertilizer P applied in the native soil, with no significant differences between the 8-3-5 and 6-7-0 fertilizers. In the sand/peat root zone mix the P effectiveness averaged 0.105 mg/kg Bray-1 P for every kg/ha fertilizer P applied, also with no differences between fertilizer sources. This suggests that the organic fertilizers had similar effects on soil test P per unit P applied, despite differences in the PSI of the two materials. Soil appeared to have a greater influence on P effectiveness than fertilizer, with the sand mix having a greater P effectiveness (less buffering) than the native soil. This is consistent with conclusions reached by Sneller and Laboski in agricultural soils fertilized with different types of manure. Because each experiment had only one synthetic P treatment, we could not calculate the P effectiveness of the synthetic P fertilizer in our soils.

The sand/peat experiment can be considered a worst case for soil response to P application, because the coarse-textured soil is poorly buffered and P application rates were higher than those used for home lawns. When organic fertilizer with high P concentration and high PSI was applied to the sand/peat plots, significant increases in both Bray-1 P and soil PSI were observed after 3 years. Although it would take longer, similar changes would occur in the native soil, eventually increasing the risk of leaching and runoff loss of P.

These results show the importance of evaluating fertilizer sources for the amount and availability of P. The soil test results show that Bray-1 P was higher when using P-rich organic fertilizer, compared with synthetic fertilizer containing P, because of the greater P application rate from the organic fertilizer when applied at rates to meet N needs. The greatest increase in Bray-1 P occurred in the sand-based fairway treatment. Changes in soil PSI were smaller, indicating only small changes in P saturation and the risk of P loss from the soil over the 3-year duration of this study.

Some organic fertilizers could have sufficiently low P concentrations and PSI values that they could be used for years without risk of increasing P loss from soil, but that did not appear to be the case for the fertilizers used in this study. Our results suggest that use of high-P organic fertilizers to meet turf N needs would not likely lead to increased risk of P loss in the short run, but repeated use in the long run could increase future P loss risk. This information can provide guidance for legislation regarding turf fertilizer sources, fertilization practices, and water quality. ■

**Gwen K. Stahnke, PhD, was corresponding author for this research. She is with the Puyallup Research & Extension Center for Washington State University. Other authors include: E. D. Miltner, former associate professor, and C. G. Cogger, professor, Department of Crop and Soil Sciences, Washington State; R. A. Luchterhand, research technologist III, Institute of Biotechnology, Washington State; and R. E. Bembenek, Department of Entomology, Washington State. The article first appeared in the online publication Applied Turfgrass Science in March 2013.*

▲ **WEBWORMS** — All photos provided by Rainbow Treecare Scientific Advancements

Entomology 101

Safe and effective management of shade tree pests

INSECTS ARE ONE OF THE MOST SUCCESSFUL GROUPS OF ORGANISMS ON THE PLANET. For hundreds of millions of years, insects and plants have co-evolved, sometimes antagonistically, sometimes to the benefit of both parties. Insects are also of considerable concern to arborists, but we are long past the days in which we just spray indiscriminately and hope we kill the bad ones. Insect management today requires knowledge of biology, ecology, tree physiology, phenology, and chemistry so we can protect trees with minimal impact on beneficial insects and the rest of the ecosystem. So what are the basics we need to know to safely but effectively manage shade tree insect pests?

First, we need to wrap our heads around the sheer number of insects and their diversity. The current count is more than one million named species, representing about half of all animal species alive on the planet today. The estimates of not-yet-named species is anywhere between six and 10 million species; so if you have an interest in discovering and naming new species, entomology may be the field for you. Insects are grouped with other invertebrates such as spiders, millipedes and lobsters, but have some distinguishing characteristics. Like these other arthropods (from the Greek word for "jointed leg"), insects have, of course, jointed appendages, exoskeletons made from chitin, and segmented body parts. Every organism classified into the Class Insecta will have six legs, two antennae, a three-part body consisting of a head, abdomen, and thorax, and two pairs of wings.

All insects go through some form of metamorphosis, but not all of them do it the same way. Some insects go through a complete metamorphosis (known as "holometabolis"), where the immature insect looks nothing like the adult. Look no further than the differences between a caterpillar and a butterfly to understand this process. Other examples would be grubs, maggots, and whatever you call those cool looking ladybug larvae — all of them start life with one body type, then go through a pupa stage where they emerge looking like something else altogether. The adults and their offspring not only look different, they often have completely different diets, and, often, completely different relationships to plants. As larvae, an insect may be a plant parasite eating the leaves and disfiguring the appearance, but, as an adult, they may be an important pollinator of their flowers.

> **Depending upon the source, North America has roughly 30 Orders of insects, 600 Families, 12,500 Genera, and, oh, let's say about 86,000 Species.**


Japanese Beetles


Ladybug

The other type of metamorphosis insects may undergo doesn't change their appearance much, just their size. Known as incomplete metamorphosis, or "hemimetabolis" if you prefer the Latin sound, these insects look pretty similar at all stages of life. Unlike the insects that undergo complete metamorphosis, you can often find hemimetabolic adults and immatures (called "nymphs") feeding right next to each other on the same leaf. As they grow, their rigid exoskeletons must be shed to make room for the next, larger exterior. Each time they go though one of these molting cycles, we call that an "instar." Some species may go through four to five instars before reaching maturity. This has some management implications, as certain treatments that may be effective on early instars are not as effective on more mature insects.

Depending upon the source, North America has roughly 30 Orders of insects, 600 Families, 12,500 Genera, and, oh, let's say about 86,000 Species. As noted earlier, insects are mind-boggling in their numbers and diversity, but, fortunately for arborists, not all of them are required reading. Due to their tremendous variety, it is easiest to lump them together and consider insects at the Order level. Of the dozens of recognized Orders, it really boils down to five that are of considerable concern for tree care. Just understanding the differences of these groups, and their management strategies, will go a long way toward successfully managing insects on shade trees.

Order: Coleoptera
Translation: "Sheath wing"
Holometabolis
Key tree pests: Bark beetles, leaf beetles, flathead borers, roundhead borers, weevils

When it comes to variety and diversity, no one is bigger than the beetles. With more than 400,000 recognized species, beetles make up nearly half of all known insects. Although there are certainly beetles than beneficial to trees (like the much-loved ladybug), the ones that are tree pests can be serious or even fatal health concerns. Beetles can be secondary pests, such as bark beetles affecting stress-weakened trees, or they can be primary pests, as in the case of emerald ash borer or Asian longhorned beetle. Management tools include sprays (bifenthin, pyrethroids), systemic treatments (imidacloprid, dinotefuran), and tree injection (emmamectin benzoate, imidacloprid).

Order: Hymenoptera
Translation: "Membrane wing"
Holometabolis
Key tree pests: Sawfly larvae, leafminers, gall-forming wasps, carpenter ants

While bees and wasps are certainly not widely considered to be tree pests, other close relatives in this Order can do damage to trees. Sawfly larvae, often confused with caterpillars, have an appetite for pine needles, and many common leafminers are found in this Order as well. Similar to the Coleopteran pests, management tools include sprays (bifenthin, pyrethroids), systemic treatments (imidacloprid, dinotefuran) and tree injection (emmamectin benzoate, imidacloprid).

Sawfly

Order: Lepidoptera
Translation: "Scale wing"
Holometabolis
Key tree pests: Gypsy moth, winter moth, bagworms, clear-wing borers

The Order of moths and butterflies contains many common tree pests, but they tend to only be pests as larvae. Caterpillars are one of the most common leaf-feeding insects in the world. Most do insignificant damage and require no control efforts, but some — especially introduced species — can defoliate a full-size tree in just a few days. Lepidopteran larvae are mostly thought of as leaf-feeding caterpillars, but there are a few, such as the clear-winged moths, whose larvae are wood-boring pests that can be confused with other species and are considered difficult to control. Management tools include sprays (spinosad, pyrethroids, Bt), systemic treatments (acephate), and tree injection (emmamectin benzoate, acephate).

Order: Hemiptera
Translation: "Half wing"
Hemimetabolis
Key tree pests: true bugs, leafhoppers, scales, aphids, adelgids, cicadas, psyllids

This Order has been split, lumped, and reworked more than any other in the past decade, so exactly who is now in the Hemiptera these days depends on the source, but many well-known tree pests are generally included. With a wide variety of body types, mouth parts, and feeding preferences, this group has many easy-to-control, and difficult-to-control members, so be sure you have properly identified your target for launching any control campaign. Management tools include sprays (bifenthin, pyrethroids), systemic treatments (imidacloprid, dinotefuran) and tree injection (emmamectin benzoate, imidacloprid).

Boxelder bugs

Order: Thysanoptera
Translation: "Fringed Wing"
Holometabolis
Key tree pests: thrips

Thrips, a name derived from the Greek word for "wood louse," can be disfiguring and damaging to tree leaves. In rare cases, a thrip infestation may be heavy enough to cause the death of a plant, but more often they are just damaging the leaves, buds, and flowers of trees. Although thrips are tiny, they are a well-documented vector of certain viruses that cause death to plants, particularly in agricultural or greenhouse settings. Management tools include sprays (bifenthin, pyrethroids), and systemic treatments (imidacloprid, dinotefuran).

Other Orders of insects than impact plants, but not considered prominent tree pests, include Isoptera (termites), Diptera (flies, mosquitoes), Phasmida (walkingstick) Orthoptera (grasshoppers), Odonata (dragonflies, damselflies), Mantodea (mantids) and Dermaptera (earwigs). ■

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JOHN MASCARO'S PHOTO QUIZ

John Mascaro is President of Turf-Tec International

Can you identify this sports turf problem?

Problem: Uneven playing surface
Turfgrass area: High school football field
Location: Southern United States
Grass Variety: 419 bermudagrass

Answer to John Mascaro's Photo Quiz on Page 33

Background illustration courtesy of istockphoto.com

The use of hygroscopic humectants in managing soil moisture

***Editor's note:** The author is president of BioPro Technologies; president and owner, Spindler Enterprises; agronomist and partner, Ecologel Solutions; and agronomical and research director, OJ Noer Turfgrass Research Foundation.*

MOST TURFGRASS MANAGERS are familiar with the use of wetting agents, or surfactants, and super absorbent polymers in managing water movement and retention in soils. However, there is another class of chemistry that is gaining acceptance in the management of turfgrass and ornamental soil moisture. This class of chemistry is referred to as hygroscopic humectants.

Before discussing hygroscopic humectants, it is important to understand how they differ from other water management technologies. First, wetting agents are chemicals that "reduce surface tension of water, allowing the water molecules to spread out." Another definition is "any compound that causes a liquid to spread more easily across or penetrate into the surface of a solid by reducing the surface tension of the liquid." Therefore, a wetting agent is a material that allows water to more easily penetrate into soil and/or flow through (infiltrate) the soil. These materials are valuable when soils have become hydrophobic and will not wet easily.

Super absorbent polymers, another type of water management technology, are "materials that can absorb and retain extremely large amounts of liquid relative to their own mass." These materials are utilized to absorb large amounts of rainfall or irrigation to be used by the plant at a later date. These materials are commonly used in greenhouse and nursery industries, as well as in some agricultural settings.

However, the use of polymers in turfgrass is difficult for two reasons. The first is that polymers are difficult to incorporate into the soil profile. The second is that, as they absorb water, they expand, and can disrupt the soil and turfgrass surface. However, there are some new developments in polymer technology that may overcome these challenges.

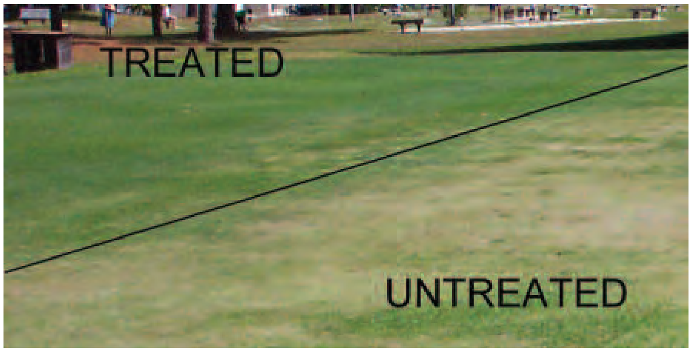
Hygroscopic humectants are materials that attract water vapor (the gas phase of water) from the atmosphere within the soil, condense it back into a liquid form, and retain the liquid for the plant to absorb. According to Merriam Webster's dictionary, a hygroscopic material is any material that "readily takes up and retains moisture." Most turf managers are more familiar with hygroscopic materials than they may realize. For instance, many fertilizer ingredients are hygroscopic. It is the hygroscopic nature of some fertilizers that cause them to "cake" or form chunks in the package.

The definition of a humectant is "a substance that promotes retention of moisture" (Merriam-Webster). These are substances that absorb, or help another substance to retain moisture. These types of materials are commonly used in the food and cosmetic industry. For example, humectants will help keep food from drying out and becoming stale. In cosmetics they help keep different types of make-up pliable so they may be applied to the skin in an even fashion without causing dryness.

The key to successfully using hygroscopic humectants to manage soil moisture is by using the right combination of raw ingredients. Some raw materials will attract moisture and condense it, but will hold it too tightly, not releasing the water to the plant. On the other hand, some raw materials may compete with the plant for soil moisture and be detrimental to plant health. Finally, some raw materials will be broken down in the soil by microbes too quickly, and have a short lived effect.

The best combination of raw ingredients are those that will attract soil water vapor to itself, condense it into a droplet, and then allow the plant root to remove that droplet for use in its metabolic activities. Another vital factor in the success of a hygroscopic humectant product is to have a certain resistance to microbial degradation. Many of the raw ingredients used in a hygroscopic humectant are organic in nature, and can be used by soil microbes as a food source. We see the same types of challenges in pesticide formulations.

Hygroscopic humectants have a variety of uses in the management of turf and landscapes. For example, they may be used in combination with wetting agents to relieve



localized dry spots. The wetting agent will allow the water to penetrate into the hydrophobic area causing the dry spot, eliminating the hydrophobic effect. Then, the hygroscopic humectant will prevent the area from drying out again, since it will be continually condensing water vapor into water droplets.

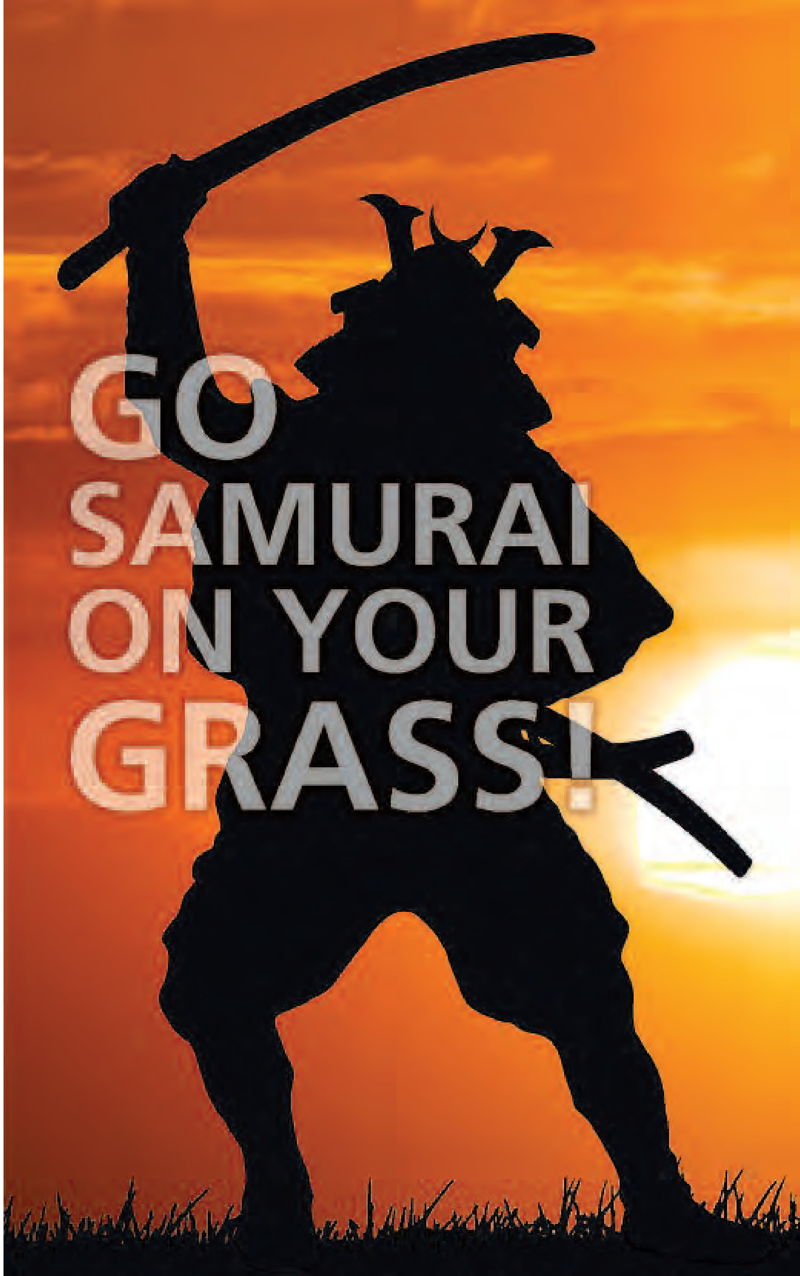
Using hygroscopic humectants is an excellent way to reduce overall landscape water use. When applied to large turf or landscape areas and watered into the rootzone, these products will allow plants to more effectively use any water they receive through rainfall and irrigation. When water is applied to the soil, it has one of three fates. First, it can be pulled down by gravity deeper into the soil and eventually added to the ground water. Secondly, it may evaporate and escape the soil back into the atmosphere above the soil. Finally and most favorably, it can be used by the plant. Hygroscopic humectants effectively minimize the loss of soil water to evaporation by condensing the escaping water vapor back into liquid form for the plant to use. In fact, these products have been documented to reduce overall water use by as much as 50%.

When seeding, hygroscopic humectants are a valuable tool to optimize seed germination and establishment. When applied over the seed and into the seedbed, these products will reduce the drying effects in between irrigation and rainfall events. Therefore, the seed is able to germinate more rapidly, and then establish and develop due to more favorable moisture conditions. This effect is also experienced in hydroseeding and sprigging.

The establishment and maintenance of trees, shrubs and ornaments are an ideal use for hygroscopic humectants. The water capturing capability of these products will allow plants to establish quickly, and survive drought conditions more successfully. The use of hygroscopic humectants in potted plants is especially valuable in reducing watering events from every day during hot, dry periods to every other or every 2 or more days. This application not only saves water, but labor as well.

Hygroscopic humectants are a valuable tool for turf managers. Used alone or in combination with other technologies, these products are valuable in reducing overall water use on all parts of the landscape. ■

Jim Spindler is president of BioPro Technologies; president and owner, Spindler Enterprises; agronomist and partner, Ecologel Solutions; and agronomical and research director, OJ Noer Turfgrass Research Foundation.



Best fertilizer management: a blueprint for success

Editor's note: *The author is a technical representative for Grigg Brothers.*

WHETHER YOU ARE MANAGING MUNICIPAL FIELDS or big league stadiums, the correct nutrient management programs will provide a blueprint for vigorous turf and prepare you—if you have not dealt with it already—if or when fertilizer use laws limit your resources. Nutrient management is one important cultural practice that forms the foundation for successful turf management; however the interpretation of soil test/water quality data, and selecting the appropriate source, timing, and rate of fertilizer is often overlooked. Many chapters in textbooks have been written on the topic of fertilizer source, selection and use so consider this short piece as a resource to help optimize your fertilizer programs and allow you to think "broad brush" about how you approach your role as a sports field manager.

UNDERSTAND PLANT COMMUNITY

First and foremost, a comprehensive understanding of the site will guide your fertilization approach. Clearly identify the turf(s) use, or function and its associated expectations. Consider safety improvements carefully. What grass(es) exist and what are their strengths, weaknesses, biology, and cultural requirements? What plants are unwanted? Soil physical and chemical properties and the time of year determine the source and frequency of fertilizer applications. For example, soil *texture* influences drainage, extent of compaction, firmness, all important factors for playability, but it also affects nutrient holding capacity and subsequently the potential effectiveness of fertilizer programs.

EXISTING OR PENDING FERTILIZER LEGISLATION

Get started now to determine how current or pending fertilizer use laws will affect your ability to manage turf in your state. New Jersey, New York, Wisconsin, Minnesota, Florida, Connecticut and Pennsylvania have or are cur-

▲ **Figure 1: IN STATES** where phosphorus (P) applications are banned, one exception is the ability to use P fertilizers on sites to establish turfgrass.