▲ **(Photo 3) Core-aerification** of an athletic field.

SOME ROOM TO BREATHE: aerification is key to plant health

I **like to think of the turfgrass plants growing on** an athletic field as a crop, not unlike the potatoes that my father raised when I was a kid in southern Idaho. And just like the potatoes, the turfgrass plants need certain inputs and environmental conditions to maximize their performance.

It has long been my opinion that the long-term potential of a playing surface, and that of the turfgrass growing on it, is directly tied to the characteristics of the soil used to construct the field. I'm not talking about the simple soil test that you might submit annually to get an idea of where you stand with regards to the status of soil pH, organic matter content, and nutrient levels. The soil characteristics you need to pay particular attention to on your fields are the soil texture, bulk density, and the effective rootzone depth. While some of these are easier to manage than others, all of them either directly or indirectly impact plant growth and the resulting quality and durability of the sports field.

» The soil characteristics you need to pay particular attention to on your fields are **the soil texture, bulk density, and the effective rootzone depth.**

Healthy turfgrass plants have actively growing rootzones that explore a large volume of the soil profile. There are a number of things that can reduce the rooting depth of turfgrass plants. For example, maintaining a turfgrass plant at a height of cut that is below its adapted range will result in reduced rooting depth as

will the development of compacted layers within the soil profile. Any reduction in rooting depth will decrease the water and nutrient uptake of the plants, which ultimately has a negative impact on plant growth. Given the intense use of most athletic fields, this is obviously a situation we want to avoid.

There has been a significant amount work done to determine the ideal range of soil textures for use on athletic fields with recommendations often varying slightly depending on geographic location and intended use. I'm not going to get into that here. Chances are that you do not have the luxury of choosing the soil texture of the fields you are managing unless you are lucky enough to be involved in a new construction project or a significant renovation. That being said, I still feel it is important that you have a good understanding of where your fields stand with regard to soil texture. In most cases it will not be necessary to submit samples for textural analysis. However, it would be good to pull some soil cores to depth of 10 to 12 inches from a few random locations in each field to get a better idea of what you are dealing with, particularly if your field was constructed using native materials.

Pay particular attention to the consistency of soil texture from top to bottom of each core and from one location to the next. While you will expect some variability from one location to the next, particularly with a native soil field, you want to see a consistent soil texture throughout the depth of the soil cores (**photo 1.**). Note any changes in soil texture as they can lead to problems with water infiltration and root growth.

Abrupt changes in soil texture in the soil profile, often referred to as layering, can impede water movement through the profile leading to the surface staying wet longer after rainfall and irrigation events (**photo 2**). If the soil surface is at or near saturation while being used, the field will wear out more quickly. To make matters worse, the water in a soil at or near saturation acts as a lubricant for the soil particles allowing them to slip past each other more easily leading to increased compaction (bulk density) of the soil.

As bulk density in the soil increases it becomes more difficult for plant roots to penetrate the soil leading to a reduction in water and nutrient uptake. In extreme cases, soil compaction can result in surface hardness (Gmax) levels that increase the risk of impact injuries to athletes using the field. For example, the Clegg Impact Tester is used to monitor surface hardness on all NFL fields. The NFL has established a maximum threshold value of 100 Gmax for all natural and synthetic fields.

Given the intense use that most athletic fields receive, effective management of soil compaction on athletic fields is just as important as a well-developed fertility program.

Once you have a good understanding of the soil conditions you are dealing with on your fields you can begin to develop an aerification program to address any problems that exist. In general, aerification practices should be conducted on actively growing stands of turfgrass. For cool-season areas you can begin a heavy core aerification program in the spring before the first fertilization followed by light coring/pencil tining during the summer months when the grasses are under more stress and more aggressive aerification again in the fall.

Aerification of warm-season grasses should not begin until late spring or early summer once the grasses are growing vigorously. In both cases, high traffic areas should be cultivated 6-8 times a year at a minimum to maximize plant health.

▲ **Left: (Photo 1) A soil core** removed from an athletic field built with a sand-based rootzone. Note the consistent texture throughout the depth of the core, lack of any compacted layers and minimal organic matter accumulation at the surface.

Right: (Photo 2) A soil core removed from an athletic field depicting the layering of different soil types. At the bottom of the core there is a fine-textured soil that is high in clay, above that there is a 4-inch layer of sand that has been topped with an additional 3 inches of fine-textured topsoil.

There are a number of different types of equipment available that can be incorporated into an aerification program and depending on your specific circumstances you might find that you need to use more than one on a regular basis.

▲ **(Photo 5) Slicer** mounted to the front of a utility vehicle.

CORE AERIFICATION

This is arguably one of the most well-known and least appreciated approaches to maintaining high quality playing fields. Core aerification removes cores of soil from the profile to a depth of 4-6 inches using hollow-tines (**photo 3, on page 8**). There are two primary types of core-aerification: drum type and cam driven. Both come in various sizes ranging from small walk-behind units to self-propelled rider-operated units and larger tractor mounted units that attach to the three-point hitch. Drum-type aerators are less expensive and require less maintenance when compared to the cam-driven unites. However, the cam-driven units have an advantage in that they cause minimal surface disruption while achieving deeper tine penetration. The cam-driven units are also capable of much closer spacing of the holes which allows for more aggressive management of compacted soils (**photo 4**). Tine diameters for core aerators range from ¼ to ¾ inch in diameter. Larger tines will remove more soil and will have the largest impact on alleviating compaction. It is important to note that using large diameter tines on athletic fields, particularly at close spacing, is not recommended during times of active use due to the risk of reduced footing stability for the athletes.

▲ **(Photo 4) Surface view** of field following core-aerification. Note the holes where soil cores have been brought to the surface to alleviate soil compaction.

SOLID-TINE CULTIVATION

Also known as pencil-tining, solid-tine cultivation is an important management tool for use during the playing season in lieu of core aerification. Using the same c am-driven equipment that is used for core-aerification, solid-tine cultivation involves the use of small diameter (1/4-inch) tines set to penetrate the soil in a very closely-spaced pattern. By using solid tines on your high-traffic areas during the season you can improve root health by temporarily reliving compaction while causing minimal disruption to the surface. Solid-tine aerification is not a replacement for core aerification in your overall management program.

DEEP-TINE CULTIVATION

This approach to compaction management uses large diameter tines (3/4-inch) that penetrate the soil to a depth of 8-1 inches. Many manufacturers design their deep-tine cultivators in such a way that they cause fracturing (shattering) of compacted layers in the soil profile upon entry/exit of the tines. This is a great tool to use two or three times a year on fields receiving extensive use.

SLICING/SPIKING

This process involves the use of narrow elongated blades mounted to a drum and rolled across the surface of the field (**photo 5**). This causes minimal damage to the surface, stimulates plant growth and improves gas exchange with the rootzone. While this will not improve soil compaction it is a very impor-

tant tool for improving plant health and should be used as often as possible.

DEEP DRILLING/DRILL-AND-FILL

Deep drill and drill-and-fill machines use a series of drill bits arranged in a grid to penetrate the soil to a depth of 10-12 inches. In many cases, this equipment allows turf managers to penetrate compacted layers that might exist deeper in the profile to improve subsurface drainage. Drill-and-fill machines have the added benefit of allowing turfgrass managers the option of filling the holes back with a soil amendment of their choice. In poorly drained soils and soils that with abrupt changes in soil texture within the profile it is common to fill the holes back with a coarse sand to improve infiltration rates. The primary disadvantage of these systems, if it is to be considered one, is that they are very slow taking 12 or more hours to cover an acre.

HIGH PRESSURE WATER INJECTION

These systems use high-pressure water that is directed through small-diameter nozzles in short bursts as the unit travels across the field. These short bursts of water can penetrate the soil to a depth of 6-8 inches depending on soil conditions. In at least one case, the equipment is designed to facilitate back-filling the holes with sand or other soil amendments. The primary benefit of high-pressure water injection systems is that they cause (almost) no visible damage to the playing surface and can be used all season long while the fields are active.

Regardless of which piece of equipment you plan to use, it is a good idea to make sure that the field is not too wet or dry before implementing your cultivation practices. Irrigate the field 12 to 24 hours before you plan to begin your work to ensure adequate soil moisture for proper penetration by the cultivation equipment while minimizing the risk of additional compaction developing as a result of your efforts.

No one piece of equipment will address each and every soil management issue that you might come across while managing your fields. It is my opinion that at a bare minimum, you should have ready access to a slicer and cam-driven core-aerator complete with sets of both hollow core and solid tines to use regularly for managing soil compaction on your fields. ■

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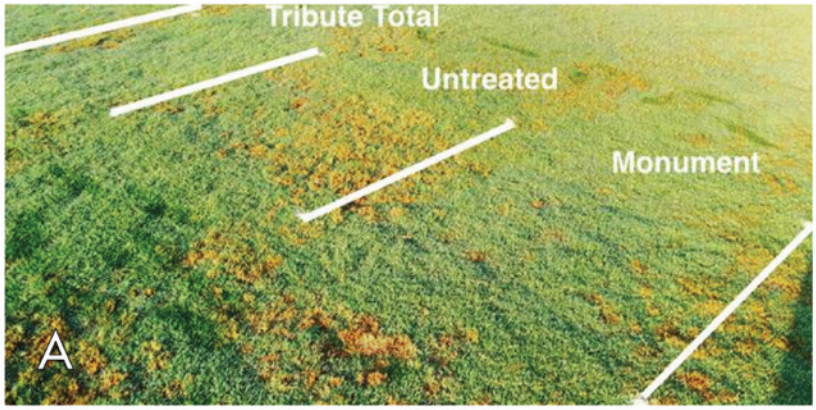
MANAGING WINTER ANNUAL WEEDS



Winter annual weeds such as annual bluegrass (*Poa annua*), henbit (*Lamium amplexicaule*) and common chickweed (*Stellaria media*) often invade cool and warm-season athletic fields subjected to traffic from fall sports such as football and soccer. Traffic can weaken both warm- and cool-season turfgrass athletic fields leaving voids in the canopy for winter annual weeds to invade.

Winter annual weeds will often become established in the most heavily trafficked portions of an athletic field during late fall and early spring once fall sports are complete and turfgrasses are less competitive. In a study conducted during the winter of 2013-2014, plots receiving simulated football traffic in fall contained 35 annual bluegrass plants per 9 ft^2 compared to less than 2 plants per 9 ft^2 those not receiving traffic (**Figure 1**).

Controlling these weeds is essential to maximizing both field safety and playability. Researc h at the University of Tennessee has found that the presence of weeds on athletic fields can reduce traffic tolerance potentially leading to greater injuries. Additionally, failure to remove winter annual weeds will allow them to persist with desirable turf the following growing season (**Figure 2**); which negatively affects field playability and safety as well. To that end, it is important to develop a plan for managing winter annual weeds on athletic field turf.

COOL-SEASON ATHLETIC FIELDS

On many cool-season athletic fields, annual bluegrass is a year round problem rather than something that is seasonally troublesome. Seedhead production

◄ **Figure 1. Top Left: Annual bluegrass** invading trafficked hybrid bermudagrass turf. Few weeds are present in non-trafficked turf.

Figure 2. Non-competitive hybrid bermudagrass growth following use of POST herbicides for annual bluegrass control (A). Additionally, clumps of ryegrass competing with bermudagrass growth on a high school football field (B).

and deposition into the soil profile ensures that annual bluegrass will be a perennial problem on these fields. For example, researchers have reported that annual bluegrass deposits nearly 2 million seeds per ft2 (185,000 seeds per m2) in the top inch of soil. In these instances, climatic conditions usually favor annual bluegrass seed germination and growth for large portions of a calendar year making permanent control with herbicides difficult.

Many field managers have had success managing annual bluegrass with applications of Tenacity (active ingredient is mesotrione). Tenacity is a carotenoid inhibiting herbicide that turns susceptible weeds white after application (**Figure 3**). Researchers have observed that sequential applications of Tenacity in the fall can remove annual bluegrass from Kentucky bluegrass (*Poa pratensis*); however, responses may vary with location, year, or annual bluegrass biotype. Individuals managing fields with high percentages of perennial ryegrass *Lolium perenne*) will need to reduce application rates because this species is less tolerant of Tenacity than Kentucky bluegrass.

In addition to having activity on annual bluegrass, Tenacity can be used to control several winter annual broadleaf weeds, including common chickweed, henbit, and lawn burweed (*Soliva sessilis*) either pre- or postemergence. Label directions allow for Tenacity to be applied for weed control on fields before being re-seeded or sodded as well. However, applications after seeding should be delayed a minimum of 4 weeks or until newly germinated turf has been mowed twice.

Xonerate (active ingredient is amicarbazone) is a new herbicide labeled for use on many mature warm- and cool-season turfgrasses that has efficacy for annual bluegrass control on golf course turf with sequential applications. Despite significant interest among athletic field managers, Xonerate use on cool-season fields is limited because current labeling does not allow fall applications due

▼ **Figure 3. Annual bluegrass bleaching** after treatment with Tenacity

to injury to desirable turf. Additionally, applications in spring must be made before air temperatures reach 85°F. Moreover, applications to Kentucky bluegrass must be delayed a minimum of 12 months after seeding. Research trials have shown some benefit to tank mixing Tenacity and Xonerate for annual bluegrass control in cool-season turfgrass; however, more information is needed before this mixture becomes a labeled option that athletic field managers can legally apply to their turf. At the current time, the best use of Xonerate on athletic field turf is for annual bluegrass control on warm-season fields overseeded with perennial ryegrass for spring football and baseball.

Pylex (active ingredient is topramezone) is a new herbicide for use in turfgrass that is also safe for use on many cool-season turfgrasses including Kentucky bluegrass, perennial ryegrass, and tall fescue (*Festuca arundinacea*). Pylex works similar to Tenacity in that it inhibits carotenoid production, turning susceptible weeds white after application. Pylex is an option for postemergence weed control in established turf and can also be used when establishing new cool-season turfgrass stands from seed. However, applications after seeding should be delayed a minimum of 4 weeks. Although Pylex has**no activity** on annual bluegrass, it can be used to select winter annual broadleaf weeds such as common chickweed, speedwell species, Shepherd's-purse, hairy bittercress, and henbit.

Drive XLR8 (active ingredient is quinclorac) is often thought of as an herbicide for postemergence crabgrass control. Many athletic field managers are unaware that Drive XLR8 controls a wide spectrum of broadleaf weeds including many winter annual species. Drive XLR8 is also safe for use during the establishment of cool-season species used on athletic fields. Applications to newly seeded Kentucky bluegrass can be made 4 weeks after seeding; on perennial ryegrass, Drive XLR8 can be applied at seeding and 4 weeks thereafter as well.

Athletic field managers should be advised that many products containing quinclorac are available under different trade names. Always check the product label to determine if a particular herbicide can be applied to newly established turf. For example, SquareOne Herbicide (active ingredients are quinclorac + carfentrazone) can be applied to Kentucky bluegrass and perennial ryegrass 7 days after emergence. Comparatively, applications of Q4-Plus (active ingredients are quinclorac + sulfentrazone + 2,4-D + dicamba) must be delayed until at least 28 days after emergence.

WARM-SEASON ATHLETIC FIELDS

Winter annual weed management is a critical issue on warm-season athletic fields. As temperatures cool throughout fall and winter, warm-season turfgrasses grow less aggressively and often enter dormancy in many locations. This renders warm-season athletic fields non-competitive against winter annual weed invasion.

There are several factors that make winter annual weed management on warm-season athletic fields complicated including decisions regarding overseeding and managing the evolution of herbicide resistant weeds.

Overseeded Fields. Many warm-season athletic field managers chose to overseed fields with cool-season species such as perennial ryegrass during fall. This practice ensures that fields will remain green throughout the winter and early spring, which can be important for sports like baseball that often begin early in the calendar throughout much of the southern United States. It also serves to protect dormant bermudagrass crowns from the negative effects of foot traffic during dormancy. However, inputs of irrigation water and fertilizer nutrients required to establish a successful stand of overseeded turf on warm-season athletic fields can encourage invasion of winter annual weeds, particularly annual bluegrass. Much like controlling the winter annual weeds; overseeded perennial ryegrass must be removed in the spring for warm-season turfgrasses to recuperate.

One option for annual bluegrass management in these scenarios is to apply a preemergence herbicide like Barricade (active ingredient is prodiamine) 8 to 10 weeks before overseeding. However, in most climates annual bluegrass pressure will likely be quite low during this 8 to 10 week period before fall overseeding. Additionally, this practice may not provide complete control in most environments because multiple flushes of annual bluegrass germination can occur throughout the fall.

Another option is to apply an acetolactate synthase (ALS) inhibiting herbicide such as Revolver (active ingredient is foramsulfuron), Monument (active ingredient is trifloxysulfuron), or Katana (active ingredient is flazasulfuron) closer to overseeding. These herbicides can safely be applied 7 to 28 days before overseeding species such as perennial ryegrass into bermudagrass athletic fields. Be advised that re-seeding intervals vary by product and field managers should consult the herbicide label for more specific information. Applications of ALS inhibiting herbicides will control any annual bluegrass plants that may have emerged before overseeding and provide some residual control of those germinating thereafter.

Some field managers chose to follow-up these applications with postemergence treatments after overseeding. As previously mentioned, Xonerate is a new herbicide that fits this use pattern. Prograss (active ingredient is ethofumesate) is labeled for postemergence annual bluegrass control in overseeded perennial ryegrass turf on

▲ **Figure 4. Many warm-season athletic fields** are not overseeded during the winter and enter full dormancy.

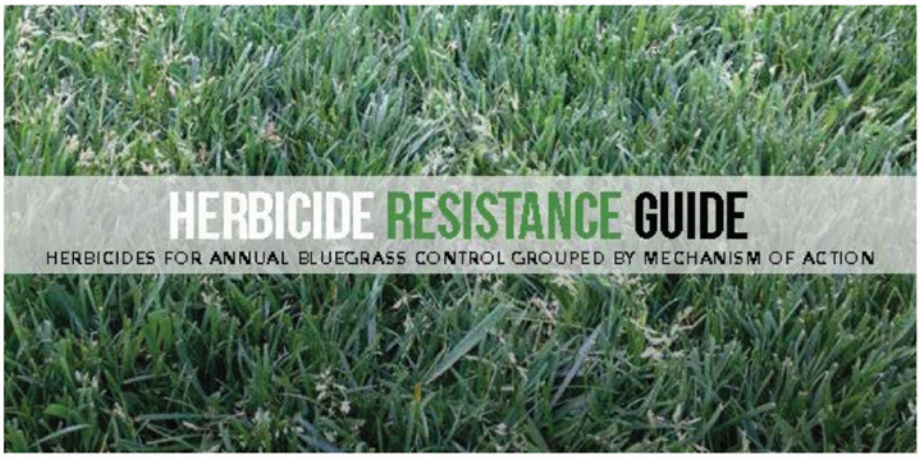
golf courses. Applications are usually made once the overseeded stand has emerged to a height greater than 1 inch and has been mowed at least a single time. Research trials have found that sequential applications of Prograss at this timing in Tennessee effectively control annual bluegrass in overseeded perennial ryegrass fairways. However, Prograss is for use by professional applicators only and does not have specific labeling for use on athletic fields.

Non-Overseeded Fields. Many facilities do not have the resources to overseed their warm-season athletic fields and turf remains dormant throughout the winter and mid-spring (**Figure 4**). In these situations, pre- and postemergence herbicides can be used to manage winter annual weed infestations.

There are numerous preemergence herbicide options for controlling annual bluegrass and other winter annual weeds on non-overseeded bermudagrass including: Pendulum AquaCap (active ingredient is pendimethalin), Barricade (active ingredient is prodiamine), Dimension (active ingredient is dithiopyr), Echelon (active ingredients are prodiamine + sulfentrazone), Specticle Flo (active ingredient is indaziflam), Ronstar (active ingredient is oxadiazon), and Princep (active ingredient is simazine). Most of these herbicides are applied in early fall to provide residual control of annual bluegrass plants not yet emerged from soil for several weeks after application. Specticle Flo, Echelon, and Princep can be applied later in the fall to control newly emerged annual bluegrass plants in addition to offering residual control of plants that have not emerged from soil. Consult a local Extension specialist for specific information about best application rates and timings for these herbicides.

Concerns over traffic tolerance and recovery often result in many athletic field managers avoiding use of preemergence products in fall when fields are subjected to traffic. As a result, postemergence herbicide applications for winter annual weed control are more common on athletic fields. ALS inhibiting herbicides such as Revolver (active ingredient is foramsulfuron), Monument (active ingredient is trifloxysulfuron), or Tribute Total (active ingredients are thiencarbazone + foramsulfuron + halosulfuron) are often applied in spring once turf begins actively growing. Katana (active ingredient is flazasulfuron) is another ALS inhibitor that can also be used for annual bluegrass control in spring if applied following an application of quickly available nitrogen fertilizer at greater than 0.5 lb N/1000 ft2. ALS inhibiting herbicides can be used at low application rates to control annual bluegrass and a wide spectrum of winter annual broadleaf weeds when soil temperatures exceed 60°F. They are commonly applied with non-ionic surfactants at a 0.25% v/v ratio to improve performance.

A common practice in the transition zone is to treat dormant bermudagrass athletic fields with applications of the non-selective



TIMING	ACTION	ACTIVE INGREDIENT*
Pre/Post	Mitotic inhibition	Dimethenamid (Tower**)
		Pronamide (Kerb)
	Photosystem II inhibition	Amicarbazone (Xonerate)
		Atrazine (Aatrex)
		Metribuzin (Sencor)
		Simazine (Princep)
	Cellulose biosynthesis inhibition	Indaziflam (Specticle)
	Lipid biosynthesis inhibition	Ethofumesate (Prograss)
	Carotenoid biosynthesis inhibition	Mesotrione (Tenacity)
	Protoporphyrinogen oxidase (PPO) inhibition	Flumioxazin (SureGuard)

▲ **Figure 5. University of Tennessee,** for selecting herbicides for annual bluegrass control.

herbicide Roundup Pro (active ingredient is glyphosate) to control annual bluegrass and other winter annual weeds. Roundup Pro is labeled for use on dormant bermudagrass turf at rates of 5 to 44 fl oz/A and provides a more economical alternative to many of the ALS inhibitors. Applications must be made to **completely dormant** turf (i.e., no green leaves or stolons present) early in the year at air temperatures > 50F. Be advised that applications under cooler conditions will not be as effective and those made to partially dormant turf can severely stunt spring green-up. Other non-selective herbicides that fit this use pattern include Finale (active ingredient is glufosinate) and Reward (active ingredient is diquat). Be advised that burndown products such as Reward may require sequential applications to provide acceptable control.

Herbicide Resistance. A major factor complicating programs for managing winter annual weeds (particularly annual bluegrass) in warm-season climates is the increasing incidence of weeds exhibiting herbicidal resistance. Weeds are deemed "herbicide resistant" when they are no longer controlled by a rate of a particular herbicide that was once normally effective. Over the past several years there have been first reports of annual bluegrass populations developing resistance to commonly used herbicides including Barricade, Monument, Revolver, Princep, and Roundup. In nearly all of these cases, resistance developed as the result of using the same herbicide for a series of consecutive years without rotation. This all-to-common process essentially removes annual bluegrass plants that are sensitive to a particular herbicide and selects for those with some inherit level of resistance. Recently, populations of annual bluegrass with resistance to multiple herbicidal modes of action have been identified in the southeastern United States.

An increase in herbicide resistant annual bluegrass will result in field managers having fewer herbicide options for annual bluegrass control. Several turf managers are already struggling with the stark reality that resistance brings to light. Imagine annual bluegrass that could not be controlled with Revolver, Monument, or Princep. What about annual bluegrass that remained on dormant bermudagrass fields after an application of Roundup? Continued use of the same weed management strategy for multiple years will eventually lead to this result at some point in time. It is critical that field managers diversify their strategies for annual bluegrass control now and rotate their approach regularly. The University of Tennessee has developed a guide to assist field managers in rotating herbicides for annual bluegrass control in an effort to reduce the rate at which herbicide resistance in turf has been increasing. This document essentially groups products for annual bluegrass based on optimal application timing (i.e., pre- or postemergence) and color codes herbicides by their mode of action (**Figure 5**).

Winter annual weed management is an important issue for individuals managing both cool- and warm-season athletic fields. Failure to control winter annual weeds can negatively affect field safety and playability. Winter annual weeds left uncontrolled often can persist into the following season, competing against desirable turf for valuable water, light, and nutrient resources. It is critical that field managers developing a plan for managing winter annual weeds and commit to rotating their approach regularly to mitigate to the development of herbicide resistant weeds. ■

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HOW TO AVOID THE FIELD WORK DAY BEFORE NEXT SEASON

▲ **Turfplaning the outfield** at the University of South Alabama, Mobile. The turfgrass manager is Zach Willard.

As we all realize, maintaining athletic fields and facilities can be a year round job for the coaches, groundskeeper, booster clubs, maintenance staff, etc. So often we hear of coaches setting a work day in January for "all hands on deck" and a long 12-hour or more day is spent edging, painting, cleaning bathrooms, concession stand etc. Here we will hopefully give you some ideas that can be put in place throughout the year that will help you avoid this on a cold, cloudy, dreary January day.

Typically, in most sports, there is some down time for the field. With travel ball, select tournaments and various leagues throughout the country, finding the down time is important and must be scheduled just like the weekend tournaments. Coaches and players might not like having access to the fields, but, if they realize that this is to keep them safe and playable, then it is easier for them to understand.

For timing purposes, we will use the baseball/softball season for colleges/high schools/parks and recreation (typically January 1 through June 30 in the South). As you are reading this, you might think "That doesn't happen at my location," but, with some planning, you can apply these field maintenance practices into your schedule.

JULY

The main focus during this time is your turf health. You want to aerify your fields as soon as possible to help reduce the compaction from the season and aerfiying will create space for the nutrients, water and oxygen to reach the roots to stimulate plant growth. Ideally, you will aerify in two directions immediately after the season to give your turf the most time to recover and become healthy.

Along with aerfiying, you need to topdress with sand (USGA is recommended), but, if budget or availability is a problem, you can use washed, slightly coarser sand. Try to find sand that is free of debris and rocks. After aerifying in two directions, apply a heavy layer of sand up to ¼ inch, then mat drag the field to allow the sand to help fill the space created.

Other things to consider could be: vertically mowing, replacing sod, turfplaning, sand surface leveling of your fields or major renovation projects.

AUGUST

August is a great month to add infield mix to your skinned areas. The weather is warm and drier and therefore infield material will be much easier to work. We will save the discussion for what type of infield mix to use for another day, but, basically the areas you need to address will be: Low spots on your infield; the edges of your grass and skinned infield; baselines; mounds; home plate area holding water in the batters boxes; and bullpen mounds. With the infield and mound work, it is much easier to complete this time of year and will allow for the material to settle and be ready for the season in January. Try to

have your on-field work completed this month before you overseed your field so you won't be driving over your field.

SEPTEMBER

Overseeding is the next step in your process getting ready for the season. A few things to remember and check before you begin your overseeding: Irrigation is key to establishing a great stand of your overseed variety. We recommend taking time about 2 weeks before overseeding to check your system. Monitor all irrigation heads making sure they are rotating properly and getting adequate coverage (head to head). If not, replace or repair at once. By making sure the irrigation is in proper order, it helps with your overseed establishment. Once your irrigation system is working, the next step will be to prepare your field for the seed.

Remove most of the grass on your field by lowering your cutting height while trying to avoid scalping the grass. You will need to remove the excess clippings by sweeping your field to get it clean. Once clean, you can then overseed your fields. Ideally you want to use a drop spreader around the edges (infield, plate, baselines, warning track, etc.) so that you don't spread seed where you don't want it. The drop spreader can be used on the infield and lip areas; make sure you go in two directions with the seed.

For the outfield, you can use a walk-behind rotary spreader or a machine-mounted spreader, also going in two directions. Once you overseed, keep the seed moist until it germinates and then start backing off the water to help the roots establish. If your budget allows, you can add a starter fertilizer approximately 7-10 days after overseeding. We recommend waiting until you see the grass start to push up out of the ground before fertilizing so that the plant can use the nutrients available.

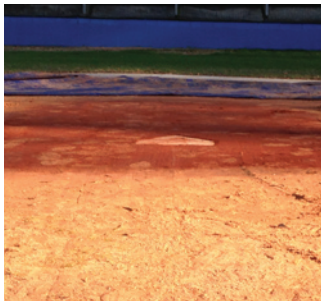
OCTOBER-NOVEMBER

If you didn't get all your clay work completed in August, now is the time to finish it and fine-tune your field. You want to minimize the traffic on your field so that the newly planted overseed won't be damaged and the field will be in great shape for the season. This is a great time to pull out your screens, nets, backstop padding, rail padding, tarps (mound/plate/bullpen), infield protectors, windscreen, etc. You will want to check for holes, tears, rips, etc that might have happened during the off-season. Repair or replace these items now and have them ready for the season in November. As with most items, once the season gets closer, manufacturers get busy and the timeframe is longer to get that replacement. Avoid the rush and shop early for items needed in January!

DECEMBER

Time will move quickly from Thanksgiving to Christmas to New Year's. With the downtime and getting ready for holidays, it is a great time for you to pull soil samples and get them to the lab for analysis. You will want to do this about the same time every year that will help you with your planning for the following year. Soil reports give you the necessary information—the good and the bad. The report allows you to target the areas that are deficient in nutrients. By having this at the first of the year, it allows you to create a game plan on how to attack your fertilization needs going into the spring. This allows your turfgrass every opportunity to be healthy and grow.

▲ **Hoover Met Field** overseeded for Hoover High School football. Sam King is the turfgrass manager.



▲ **Left: Leveling home plate** with mound clay at Stone County High School, Wiggins, MS. Field maintained by head coach Hayden Cox. **Right: Adding clay** to the Pensacola Blue Wahoos Field, Pensacola, FL, where Ray Sayre is head groundskeeper.

Yearly equipment maintenance and repair can also be on the list of things to do in December. Some things to make sure happen are: sharpen bed knives, grind reels, change oil and fuel filters, replace batteries, make sure tires are in good shape, and repair any hydraulic leaks, worn hoses, etc. Have your equipment ready for the season means one less headache to deal with in January.

JANUARY

Final step is to add your conditioner to the skinned areas. You want to put your conditioner out before you do anything on your field. If you have the December camp and you plan for infield/outfield, then adjust your timeframe and have the conditioner on the field before players are there. The last thing you want to do is to have your field looking great and a 1-day hitting/fielding camp ruin your hard work.

As with most schedules, they can and probably will be adjusted. Take the time to plan ahead. January is a great time to create a yearlong calendar for the field and begin documenting what you do to your field. By doing this, it will allow you to plan for the next year and begin a yearly maintenance/checklist and will help you avoid the "all hands on deck" field day in January. Have a great fall and we'll see you in Denver at the STMA Conference. ■

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TURFGRASS MANAGEMENT MATHEMATICS

Recently I returned to the home farm near Cameron, WI where I grew up. We were going to move the last things out of our farmhouse so it could be sold. In amongst the books in the attic was a small thin book called Arithmetic in Agriculture that must have belonged to my father when he as a student in Dairy Science at UW-Madison in the 50's. On the third page of the book, which was copyright 1951, was a picture of a young farmer in bib overalls sitting at a desk with pencil and notebook. The caption read, "Arithmetic will help you solve many farm problems." Think of this for a minute; the problems in this book were meant to be worked out without a calculator, or a smartphone, or calling a friend who is good at math. A slide rule might be helpful; raise your hand if you can work a slide rule! What a great time we live in, because all these tools are available to use today, although phone a friend is a last resort.

A firm grasp of mathematics is also vital for a turfgrass manager. If you make a math mistake you will waste time and money and eventually kill grass. Mathematics allows us to calculate how much of an input to apply, calculate the cost of different applications and determine how many workers or man hours to allow for a project. It is never a bad idea to review and sharpen our mathematical skills and this article is intended to do that. Let's review some principles before we do some calculations.

SIGNIFICANT FIGURES AND PRECISION

How accurate do our calculations have to be? It depends on the situation. If we apply a 2x rate of sand topdressing to a field we will not even notice, but a 2x rate of metribuzin and we may be looking at some dead turf. In general, we match the precision of measuring the material to the amount that is going to be applied. We handle sand topdressing with tractor scoops and topdressers and in most cases two significant figures are all that are needed. A typical π inch topdressing application applies 33 yd^3 tons per acre. The 33 represents two significant figures. An application of ammonium nitrate (34-0-0) equivalent to 1 lb N/1000 ft^2 to the playing surface of a football field would require 169.4 lbs. Do we need this kind of accuracy? Four significant figures? No, in this case we can still use two significant figures and round this number up to 170 lbs.

What if we are making an application of MSM Turf to control wild garlic on the same football field? Using the 0.5 oz per 1000 ft^2 rate this application would take 28.8 oz of product and in this instance we can again use two significant figures and round this number to 29 oz. In the case of smaller areas or products with very small use rates three significant figures may be warranted.

A POWERFUL TOOL

One of the most useful and powerful tools that is commonly used on turfgrass math is the equation of ratios. In many cases we have determined or been given the rate we need for a set area such as 5 oz of product/1000 ft^2 or 2 lbs of product per acre. We know the area over which we will be applying our product and now we must determine how much of the product to apply. For example, the label on kwiksorb wetting agent says to apply 5 fl oz of product per 1000 ft^2 or 218 fl oz/acre. We want to apply this to the playing surface of our sand-based football field that measures 360 ft x 160 ft or 57,600 ft^2. To solve this we set up the following:

$$\frac{5\ fl\ oz}{1000\ ft^2} = \frac{x\ fl\ oz}{57{,}600\ ft^2}$$

In this case our units also align so we do not have to do any conversions at this point. To solve the problem we cross multiply and divide.

$$\frac{5\ fl\ oz\ x\ 57{,}600\ \cancel{ft^2}}{1000\ \cancel{ft^2}} = 288\ oz\ of\ kwicksorb$$

We could also use the rate for an acre (43,560 ft^2) which is 218 fl oz

$$\frac{218\ fl\ oz\ x\ 57{,}600\ \cancel{ft^2}}{43{,}460\ \cancel{ft^2}} = 288\ oz\ of\ kwicksorb$$

In equal ratios the product of the means is equal to the product of the extremes. What does this mean? Let's write the equation a little different. 218 fl oz/43,560 = 288 fl oz/57,600

ft^2. The extreme values in this case are the ones on the outside of the equation and the means are those near the = sign. And 218 fl oz x 57,600 ft^2 does equal 43,560 ft^2 x 288 fl oz. (If you multiply these out there is a small discrepancy due to rounding.)

One of the most import calculations a turfgrass manager makes is the determination of how much of an input to apply to an area of turfgrass. Every calculation of this type comes down to the same principle applying an amount of a product over an area. Most discussions of turfgrass mathematics spend some time discussing the determination of areas of different shapes and even how to determine the areas of oddly shaped features such as golf greens and sand bunkers. When I think of athletic fields I don't see many of these odd shapes but mostly rectangles and quarter circle arcs of baseball and softball diamonds. For the rectangular shapes the areas are easily determined by multiplying the length by the width. Most field managers know the length and widths of their fields because at some point they have pulled a tape and measured them. With today's technology it is also fairly easy to determine areas of fields using smart phone apps such as Measure My Land, Planimeter, or Google Earth.

Nearly every product we apply to turfgrass is not in a pure form so we must determine application rates to allow for this. For example, if we are applying 21-0-0 fertilizer it only contains 21% N so even though we have applied 100 lbs. of product we have only applied 21 lbs. of N. Two applications that apply a product in a pure form are topdressing and irrigation. We will begin with some examples of those applications.

Example: How much sand topdressing is required to apply 1/4th inch of topdressing to an area of soccer fields that is 250 yards long and 75 yards wide?

A topdressing layer can be visualized as long, wide, and thin box; in this case 250 yards long, 75 yards wide and 1/4th inch thick. We have units of yards and inches so we need to convert the inches into yards.

$$\frac{1}{4}\ inch\ X\ \frac{1\ yd}{36\ inches} = 0.00694\ yds$$

$$250\ yds\ x\ 75\ yds\ x\ 0.00694\ yds = 130\ cubic\ yds$$

So we will need 130 cubic yards of sand for this application. Our sand supplier sells sand by the ton and a cubic yard of dry sand weighs 2700 lbs.

$$130\ \cancel{yd^3}\ x\ \frac{2700\ \cancel{lbs}}{\cancel{yd^3}}\ x\ \frac{1\ ton}{2000\ \cancel{lbs}} = 176\ tons$$

Now the sand is probably not totally dry depending on the weather. If I were buying sand for this application I would buy 15% extra to allow for this water.

$$176\ tons + (15\ \%\ x\ 176\ tons) = 202\ tons\ of\ sand$$

So for this application I would order 202 tons of sand.

Example: How much water is needed to apply 1 inch of irrigation to a football field with the dimensions 130 yds by 70 yds? In this case it may be easier to work in cubic feet.

$$130\ yds\ x\ \frac{3\ ft}{yd}\ x\ 70\ yds\ x\ \frac{3\ ft}{yd}\ x\ 1\ in.\ x\ \frac{ft}{12\ in.}$$

$$= 6{,}800\ ft^3\ x\ 7.5\ \frac{gallons}{ft^3} = 51{,}100\ gallons$$

Or we could do an internet search and ask "How many gallons are in an acre inch of water?"

Answer 27,152 gallons. The problem now is an equation of ratios.

$$130\ yds\ x\ \frac{3\ ft}{yd}\ x\ 70\ yds\ x\ \frac{3\ ft}{yd} = 81{,}900\ ft^2$$

$$\text{so}\quad \frac{27{,}152\ gal}{43{,}560\ ft^2} = \frac{x\ gal}{81{,}900\ ft^2}$$

Solving for x we get 51,000 gallons.

Sand and water are some of the commodities that are "pure" in that the contain 100% of their ingredient.

CHEMICAL APPLICATIONS

With the exception of fertilizer, all of our chemical applications that are sprayed or spread on turfgrass almost always come with a label that gives of a rate of product to use per area of turfgrass.

Example: We have an adult softball 4-plex with full skin infields, 65 ft bases and 275 ft to centerfield. Each field has 61,450 ft^2 of grass area. Each field is grassed with MS-Pride bermudagrass and we need to apply Primo-MAXX to tighten up our canopy and cut down on our mowing. We are treating 61,450 ft^2 x 4 = 245,800 ft^2 of grass area. The rate of Primo Maxx for athletic field height (1/2 inch) hybrid bermudagrass is 11 oz per acre.

$$\frac{11\ fl\ oz}{43{,}560\ ft^2} = \frac{x\ fl\ oz}{245{,}800\ ft^2} = \frac{11\ fl\ oz\ x\ 245{,}800\ \cancel{ft^2}}{43{,}560\ \cancel{ft^2}}$$

$$= 62\ fl\ oz\ Primo\ Maxx$$

FERTILIZER APPLICATIONS

Fertilizers are a bit different than other chemical applications in that they are made in response to a soil test or fertility plan, and we must take into account the percent element of interest (usually N) in the fertilizer.

For example we have 233,000 ft^2 of bermudagrass soccer fields on soils modified with shallow sand cap. Our fertility plan calls for 1.5 lbs of N per 1000 ft^2 for the months of June, July, August and September. Our soil test also indicates we need to apply some potassium per our soil test so we choose a 20-0-20 fertilizer. How much 20-0-20 do we need to purchase?

$$\frac{1.5\ lbs\ of\ N}{1000\ \cancel{ft^2\ month}} \times 233{,}000\ ft^2 \times 4\ months$$

$$= 1{,}398\ lbs\ of\ N\ are\ needed\ for\ the\ summer$$

To supply this we are using 20-0-20 which is 20% by weight N. In this case we **divide** the amount of N we need by the percent N in the fertilizer expressed as a decimal.

$$\frac{1.398\ \cancel{lbs\ of\ N}}{\frac{0.2\ \cancel{lbs\ of\ N}}{1\ lb\ of\ fertilizer}} = 6{,}990\ lbs\ of\ fertilizer$$

Whether we choose to buy the fertilizer in seven 1000 lb bulk bags or 140 50 lb bags we will need to buy 7000 lbs of fertilizer. How much product will we need to apply per 1000 ft^2?

$$\frac{1.5\ \cancel{lbs\ of\ N}}{\frac{0.2\ \cancel{lbs\ of\ N}}{1\ lb\ of\ fertilizer}} = \frac{7.5\ lbs\ of\ fertilizer}{1000\ ft^2}$$

One last problem. We have a 2 youth baseball fields with 140,000 ft2 of tall fescue that have become infested with chickweed and shepherds purse. We have chosen to apply a 19–0–10 fertilizer product impregnated with Confront herbicide at the rate of 0.68% active ingredients (aI). Our crew applies 8 50 lb bags of the product to the area while the foliage is moist to be most effective. To be effective in killing these weeds Confront needs to be applied at a rate of 0.75 lbs of aI per acre. Was enough Confront applied to be effective?

We applied 8 bags X 50 lbs/ bag = 400 lbs of fertilizer. The fertilizer contained 0.68% aI. So we applied

$$400\ \cancel{lbs\ fert.} \times \frac{0.68\ lbs\ of\ aI}{100\ \cancel{lbs\ fert.}}$$

= 2.7 lbs aI applied, but does this meet or exceed 0.75 lbs aI per acre?

$$\frac{0.75\ lbs\ aI}{43{,}560\ ft^2} = \frac{x\ lbs\ aI}{140{,}000\ ft^2}$$

= 2.4 lbs of aI needed so we have applied enough Confront to be effective.

Our fertility program recommends that we apply 1.5 lbs of N/1000 ft^2 to the fields as well.

$$\frac{1.5\ lbs\ N}{1000\ \cancel{ft^2}} \times 140{,}000\ \cancel{ft^2} = 210\ lbs\ N$$

Have we applied enough N?

We applied 400 lbs of fertilizer that contained 19% N or 400 lbs X 0.19 lbs N/lb = 76 lbs N so no we did not apply enough N. In fact we need to apply 210 lbs N – 76 lbs of N = 134 lbs N short. We have some 30-0-0 in the shop. How much 30-0-0 will we need?

$$\frac{134\ lbs\ N}{\frac{0.3\ lbs\ N}{1\ lb\ fertilizer}} = 447\ lbs\ of\ 30\text{ - }0\text{ - }0$$

For practical purposes we would apply 450 lbs of 30-0-0 or 9 50 lb bags.

Now to make these applications we need to calibrate our equipment. Calibration is a separate process from these mathematic problems and should be the subject of a future article. Errors are often made when these processes are combined. They are best uncoupled in my opinion. A very efficient turf manager I know has his crew spend time in the winter calibrating their fertilizer spreaders with all the products they plan to use in the upcoming year.

I hope I have given you some problems that you can follow. Now, go practice. ■

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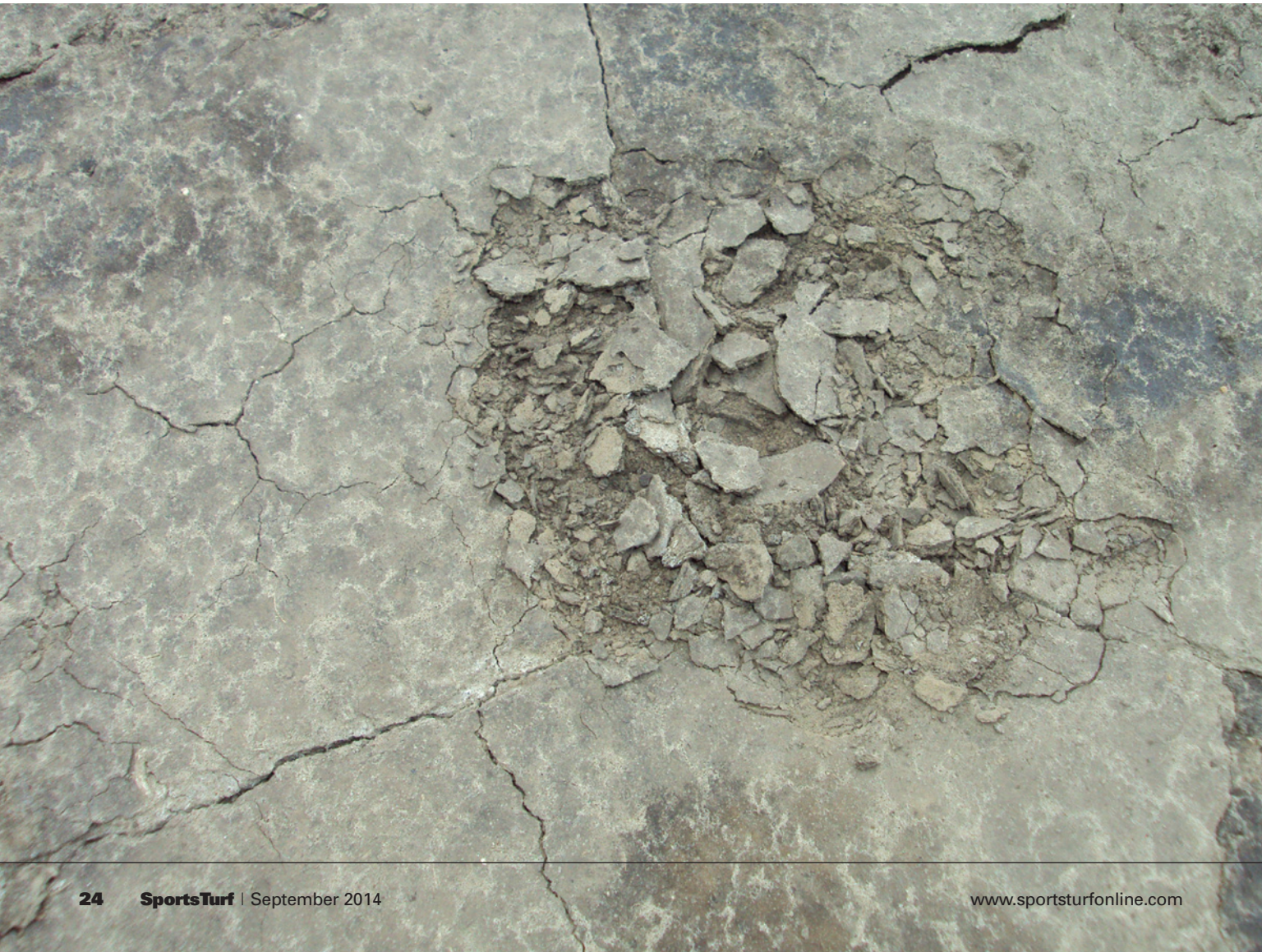
CALCIUM AND CALCIUM -BASED SOIL AMENDMENTS IN TURFGRASS

Editor's note: *The author is director of research and development for Calcium Products, Ames, IA.*

▼ **Dispersed, sodic soil** with classic surface crusting. Poor infiltration and seedling emergence can be expected.

The importance of calcium in any plant/soil system cannot be overstated. It is both a vital nutrient for plants and essential cation in soil, found in great quantities in both environments, making it somewhat unique in comparison to other elements. Although technically considered a secondary macronutrient, its level in turfgrass plants ranks third after nitrogen and potassium. Despite the relative importance of calcium, it is often ignored or simply taken for granted by those managing the plant/soil system.

Calcium plays many roles in plant health, the most recognizable being its role in strengthening cell walls and within cells to maintain osmotic balance, thereby stabi-



lizing cell membranes. Since calcium is an important component of cell walls, its presence is also important in the presence of plant stressors as cell walls are normally one of the first areas invaded by pests. Calcium binds to pectin chains in turf cell walls, giving them stability and rigidity and also is necessary for the secretion of lubricating mucilage at root tips to aid in penetrating the soil. With a healthy root system and strong cell walls being important components of traffic tolerance, you can see how important calcium is on a highly trafficked athletic field. Calcium also plays an important part in the uptake of potassium and magnesium, which are both regulated by the amount of calcium ions found within the plant; a calcium deficiency results in increased susceptibility to red thread and *Pythium* blight.

The main reason that calcium is generally ignored in the turfgrass arena is that true calcium deficiency in grasses is rare. Monocots such as turf have a relatively low requirement for calcium when compared to dicots, with typical ranges from 0.3 to 1.25% and 0.5 to 2.0% and higher, respectively. Due to low cation exchange capacity and higher leaching potential, sand-based athletic fields may be one area that turf managers should monitor calcium levels in the plant and apply supplemental applications as necessary to ensure strong, healthy turf that will resist disease and traffic pressure. If deficiency does show up, it is displayed on new leaves that appear distorted, reddish-brown in color, and may wither and die; shortened and stunted roots may also result and are the predominant deficiency symptom in soils that contain toxic levels of aluminum, magnesium, hydrogen, and sodium that outcompete calcium on cation exchange sites.

Many soils in the United States contain sufficient calcium, which makes it easy to ignore. Soils in the Midwestern US routinely contain upwards of 80% calcium on base saturation in soil tests. However, turf mangers who deal with soils that are aided by calcium-based soil amendment applications know well the importance of them in their management programs. Soils in the both the western and SE United States are ones traditionally associated with benefitting from calcium-based soil amendment applications. In the west, sodic soils are a widespread problem, and in the SE, low pH and subsequent aluminum toxicity are widespread. The mechanisms in which calcium solves these problems are different, but similar. In sodic soils, calcium is applied to replace sodium on cation exchange sites, allowing the sodium to be leached from the soil profile. Removing the sodium improves soil structure via flocculation, or 'bringing together' of soil colloids, which create aggregates, which are partially responsible for creating pore space in soils. Sodium is considered a dispersive cation and will create problems with infiltration, crusting, and seedling emergence. In soils with high levels of exchangeable aluminum, calcium sulfate (gypsum) applications help to suppress the aluminum by forcing it to react with the sulfate, creating aluminum sulfate and other compounds which are less toxic or not available for plant uptake.

Low pH is another area where calcium-based soil amendments are helpful in turfgrass. Calcitic limestone (calcium carbonate) is the predominant material used in most of the US to ameliorate low pH soils to help improve nutrient use efficiency and overall growing conditions. Although most turfgrasses tend to grow in a wide range of pH, it's an important agronomic principle for turf managers to keep an eye on and maintain in acceptable range. Dolomitic limestone (calcium/magnesium carbonate) should be used where magnesium is deficient.

▲ **Supplemental calcium application,** resulting in less winterkill.

Increasingly, more turf managers are using effluent water for their athletic fields, which can contain appreciable amounts of sodium, leading to problems where calcium-based product applications (i.e. gypsum) may become necessary. Similarly, as usage and weather patterns change across parts of the upper Midwest, sodic soils are becoming more widespread. Researchers at Colorado State University are examining the beneficial use of calcium-based soil amendments to reclaim soils that receive heavy sodium loads from effluent water. It is important to have water tested before using so you can develop a plan to combat any potential problems the water may cause.

Many people are confused as to the difference between saline and sodic soils, and this is an important distinction when it comes to gypsum soil amending. Sodic soils are exactly that, containing appreciable sodium, and saline soils can contain a wide variety of salts that need to be leached, not necessarily displaced by the calcium in gypsum. Soil testing should form the foundation of your maintenance program in these situations and contacting your local university extension service or fertilizer dealer can help you differentiate between these difficult soil types and where amending is appropriate.

Calcium is an extremely important element in any turfgrass environment, and its abundant presence, absence, or being overshadowed can make it easy to ignore or in high demand. Being able to identify where calcium-based products are needed is an important part of providing suitable growing conditions for your fields. ■