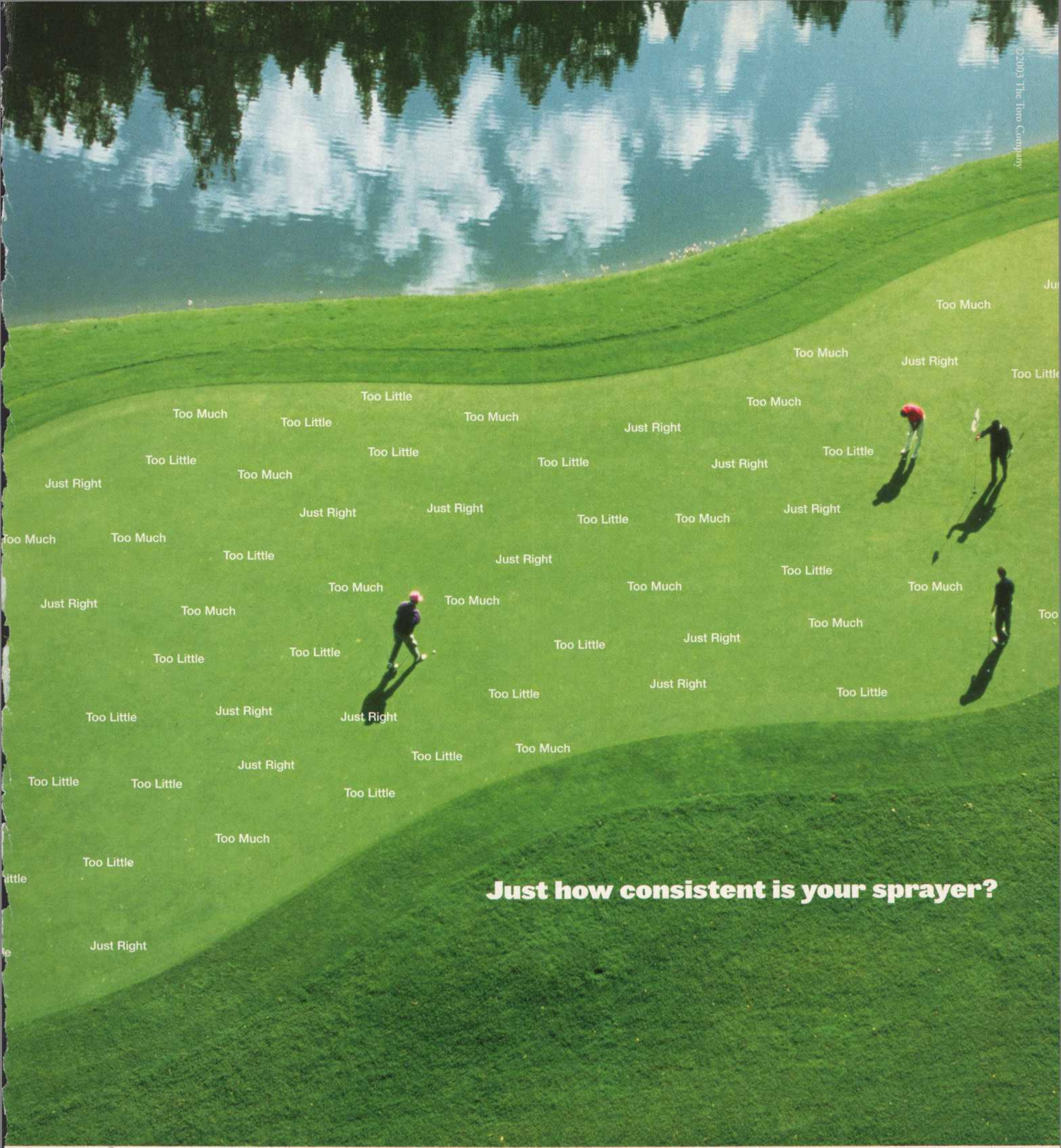

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TABLE 1

Efficacy ratings for Insignia 20WG® fungicide based on published reports available to the authors as of February, 2003.

DISEASE (PATHOGEN)	EFFICACY OF INSIGNIAA
Anthracnose (Colletotrichum graminicola)	++
Bentgrass Dead Spot (Ophiosphaerella agrostis)	L
Brown Patch (Rhizoctonia solani)	++++
Dollar Spot (Sclerotinia homoeocarpa) (suppression only)	++
Fairy Ring (various basidiomycete fungi)	L
Fusarium patch (=Microdochium Patch) (Microdochium nivale)	+++
Gray Leaf Spot (Pyricularia grisea)	++++
Gray Snow Mold (Typhula incarnata)	NA
Leaf Spot (Bipolaris, Drechslera, Exserohilum)	L
Melting Out (Drechslera poae)	L
Pink Patch (Limonomyces roseipellis)	L
Pink Snow Mold (Microdochium nivale)	+++
Pythium Blight (Pythium aphanidermatum, Pythium spp.)	++
Rapid Blight (Labyrinthula spp.)	L
Red Thread (Laetisaria fuciformis)	++++
Rust (Puccinia and Uromyces spp.)	+++
Summer Patch (Magnaporthe poae)	L
Take-All Patch (Gaeumannomyces graminis var. avenae)	+++

[a] **Rating system for fungicide efficacy is as follows:**
++++ = consistently good to excellent control in published experiments
+++ = good to excellent control in most experiments
++ = fair to good control in most experiments
+ = control is inconsistent between experiments, but performs well in some instances
= no efficacy
L = limited published data on effectiveness
NA = not applicable to Kentucky

Continued from page 60
where resistance to strobilurin fungicides is known to occur, there will be generally no value in using Insignia to control that disease. (There may be occasional exceptions to this statement, depending on the particular resistance mutation present at the site, but these exceptions are not expected to be common.)

Given the high risk of resistance to pyraclostrobin, it is strongly recommended that users be familiar with the section in the label on "Resistance Management."

Vincelli is an extension professor and Dixon is a research analyst in the Department of Plant Pathology at the University of Kentucky.

Syringing Can Dramatically Affect Canopy Temperature

By Karl Danneberger and David Gardner

Maintaining creeping bentgrass and/or annual bluegrass putting greens during the summer months is a challenge that faces many superintendents. High summertime temperatures, both air and soil, contribute to the decline of highly maintained putting greens. The decline in turf quality is directly related to morphological changes including reduction in shoot growth, root growth, stand density and leaf size caused by temperatures above the optimum for growth.

Although directly changing the ambient temperature is improbable, modifying the internal plant temperature through management practices is possible. One of those practices, syringing, is often used in an effort to lower turf canopy temperatures. To understand when and where syringing works, a brief overview of factors involved in plant temperature is needed.

Canopy temperature

The turfgrass plant/leaf temperature is governed by three major components — net radiation, convection/conduction and transpiration. Net radiation is the radiation that is absorbed directly from the sun or from long wavelengths reflected by plants or objects in close proximity (heat wavelengths), minus what the plant transmits or reflects.

Radiant energy from the sun can increase the temperature of the plant 13 degrees F to 17 degrees F beyond the ambient temperature. For example, under sunny skies and adequate soil moisture, we have measured creeping bentgrass canopy temperatures of 105 degrees F when the ambient temperature was 88 degrees F. As a general rule, canopy or leaf temperatures are 15 degrees F warmer than the ambient temperature on sunny, still days where soil moisture levels are adequate. Canopy temperatures on cloudy days, however, are closer to the observed ambient temperature.

Dissipation of heat from net radiation is accomplished through conduction/convection and transpiration. Conduction occurs when the air molecules closest to the leaf blade are heated, thus transferring some of the heat away from the leaf blade. Convection occurs when the warmer air near the leaf blade rises, being replaced by colder air. Of these two processes, convection plays the major role in heat dissipation.

Transpiration is basically the transfer of heat from the plant to the atmosphere through evaporation. Evaporation is the process where water is converted from a liquid to a gas and subsequently the conversion of sensible heat to latent heat. Sensible heat is defined as the heat energy stored in a substance (in this case water) as a result of an increase in its temperature. Latent heat is defined as the heat that flows from a material without change to temperature. In this case, the water would go from a liquid to a vapor.

The conversion of water from a liquid to a gas requires 570 calories per gram of water. Thus the removal of this heat energy through evaporation is how the plant cools itself.

Stomates (small openings in the plant where the water vapor escapes) play an important role in the ability of plants to transpire. The water vapor that surrounds the leaf blade is termed the boundary layer. The thickness of the boundary layer is dependent on the transpiration rate, relative humidity and wind velocity. The thicker the boundary layer is, the greater the resistance to transpiration (and thus cooling) is.

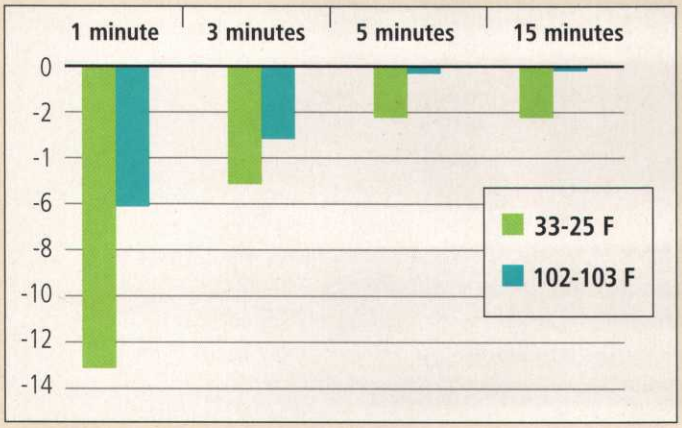
The boundary layer is thicker if the relative humidity is high and little wind is present. Conversely, if relative humidity is low and wind is present, the boundary layer is thinner.

Air movement cannot be overemphasized in its role as a cooling mechanism for turfgrass plants. In our studies, we have observed that a slight breeze (less than or equal to 5 mph) can result in a 7 degree F to 10 degree F drop in the canopy temperature. From a practical standpoint on sunny calm days, the use of a fan around greens with restricted air movement during the afternoon can help alleviate heat buildup.

Continued on page 64

FIGURE 1

The effects of syringing water temperature on the *canopy* temperature of creeping bentgrass turf mowed at fairway heights.



▲ **Figure 1.** The y-axis is the difference between the syringed canopy temperature and the nonsyringed canopy temperature. In this case, 0 would represent no difference in temperature between the syringed and nonsyringed. The more negative the number the greater the temperature depression caused by syringing.

Continued from page 63

Syringing: Mechanism to cool the plant?

Syringing is the light application of water to the turf to prevent wilt and reduce the canopy temperature. There is no exact amount of water applied during syringing that defines this practice.

In several published studies, the amount of water used for syringing varies from .06 to .25 inches per application as a definition of a syringe treatment. The effect of syringing on canopy temperature is variable depending on the environmental conditions present. In situations where wilt is occurring, syringing effects are dramatic. Where localized dry spot areas were syringed, the canopy temperatures were lowered 25 degrees F for more than an hour. In the same study, syringing areas showing visible wilting reduced canopy temperatures 10 degrees F to 15 degrees F. The application of a light amount of water to a moisture-stressed turf is effective in alleviating the stress.

In situations where wilt is not present, the effects of syringing appear to be minor. A Michigan study reported canopy temperature depression of 2 degrees F to 3.5 degrees F for two hours on a creeping bentgrass turf. In North Carolina, syringing did not significantly reduce the canopy temperature on non-wilting creeping bentgrass maintained at putting green heights. The author questioned the use of syringing under adequate soil moisture.

However, in a study conducted in Alabama, syringing was found to reduce soil temperatures when air temperatures were above 90 degrees F.

Our studies this past year confirmed several of the conclusions reported in prior studies. On a creeping bentgrass turf maintained at fairway height under wilt-free conditions, we found syringing had little effect on reducing canopy temperatures beyond 10 minutes. We did, however, find that what canopy cooling effect we did observe was greatest when ambient air temperature was high (more than 88 degrees F).

Additionally, we looked at what effect the water temperature would have on cooling. Comparing a cold water (meaning a water temperature between 33 degrees F and 35 degrees F) and a warm water (meaning a water temperature between102 degrees F to 103 degrees F), syringe, no difference in canopy temperature was detected beyond the first minute (Figure 1). This would be expected, given the nature of latent heat transfer mentioned previously in water evaporation.

Summary

Syringing applied under wilting conditions has a dramatic effect on canopy temperature. Under nonlimiting soil moisture conditions, syringing has little to minor impact on lowering canopy temperature. However, as ambient temperatures increase, the effects of syringing increase.

Danneberger and Gardner are members of the Department of Horticulture and Crop Science at The Ohio State University.

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Less Familiar Nutrients Also Deserve Spotlight

By Richard J. Hull

In this series on the mineral nutrition of turfgrasses, we have discussed all six macronutrients and the eight micronutrients. However, the subject would not be complete unless some recognition was given to the beneficial but less familiar beneficial nutrients. These beneficial elements generally are present in turfgrass tissues but they do not meet one or more of the four criteria for essentiality. The presence of these elements does have a beneficial effect on turf growth, however. Turfgrasses can grow to maturity in the absence of these elements, but growth is better when they are present.

In 1939, Daniel Arnon and Perry Stout published a set of criteria to judge a mineral element's essential role in plant nutrition. The three criteria proposed by Arnon and Stout are the following:

- In the absence of the element in question, a plant cannot complete its vegetative or reproductive life cycle.
- Deficiency symptoms of the element in question can be prevented only by supplying that element.
- The element in question must directly satisfy a nutritional requirement of the plant apart from any effects it may have in favoring the growth of a beneficial microorganism or alleviating the effects of a toxic soil chemical.

Over time, a fourth criterion was added: The element in question must be found essential for the majority of plants or at least for a significant plant group.

While these criteria for essentiality have been criticized as not strictly applying to several elements that are generally accepted as required by plants, they remain the only widely applied standards. A more significant criticism of these criteria is their exclusion of several elements that have been found to be beneficial to plants but fail one of the criteria.

Frequently, the inability to identify a specific metabolic function for an element excludes it from being classified as essential even though its beneficial properties are widely recognized. The universal criterion also excludes some elements from achieving the rank of essential.

Beneficial elements

In his book, *Mineral Nutrition of Higher Plants*, Horst Marschner (1995) discusses five elements as generally regarded as beneficial to plants and probably essential for some. These are summarized in Table 1.

Cobalt (Co), both free-living and those that grow symbiotically in plant roots, is required by bacteria, especially those capable of fixing

Continued on page 66

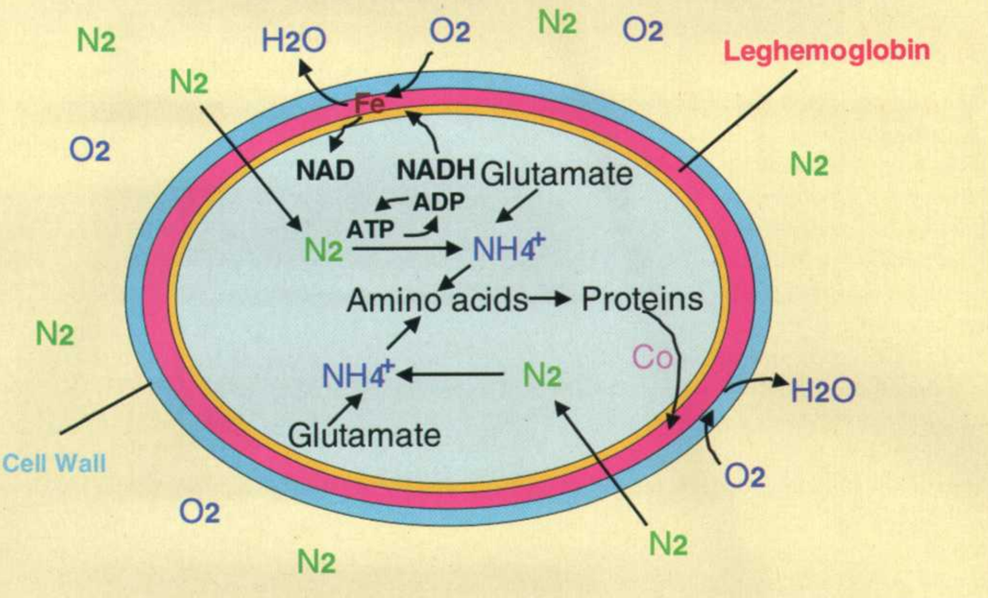
TABLE 1

Mineral elements generally thought to be beneficial to plants at some concentrations.

ELEMENT	CHEMICAL symbol	IONIC FORM absorbed by plants	CONCENTRATION* In soil sol. mg/L	In plant mg/kg
Sodium	Na	Na^+	2.3-25	680
Silicon	Si	H_4SiO_4	7-40	16800
Cobalt	Co	Co^{+2}	0.05-2.0	0.05-0.3
Selenium	Se	SeO_4^{-2}	2-4	<10
Aluminum	Al	$Al(OH)_2^+$	<1	153

* Elemental concentration typical of turfgrasses and slightly acid soils

How Leghemoglobin blocks O_2 entry into N_2 fixing bacterial cell



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atmospheric nitrogen (N_2). The latter include most legumes and several woody plant species. Here, the host plant maintains the bacterial cells in fleshy nodules that grow from roots much like lateral roots.

Because the enzyme that fixes N_2 (nitrogenase) is poisoned by oxygen (O_2), the bacterial cells must be maintained in an anaerobic space if they are to fix N_2. This is not easily achieved in plant-root nodules growing in well-aerated soils. However, the membranes surrounding bacterial cells contain leghemoglobin that binds O_2 as it diffuses into the cells. By removing this O_2 before it can enter a bacterial cell, nitrogenase is not inhibited and can fix N_2 even when its cell is in an environment containing O_2.

The biochemical sequence of reactions, that synthesize leghemoglobin in nodule bacteria or hemoglobin in free-living N_2-fixers, requires a B_{12} cofactor that has a Co atom at its core. Thus, the N_2 fixation process will not occur unless Co is present. For plants that depend on N_2 fixation for their N source, Co is essential.

Because turfgrasses do not obtain N through biological N_2 fixation, at least not directly, Co is not regarded as essential for them. However, when turf does obtain some of its N from free-living bacteria residing within the rhizosphere of turfgrass roots, that N depends on the presence of Co. This is most likely to be significant for warm-season grasses growing in subtropical areas.

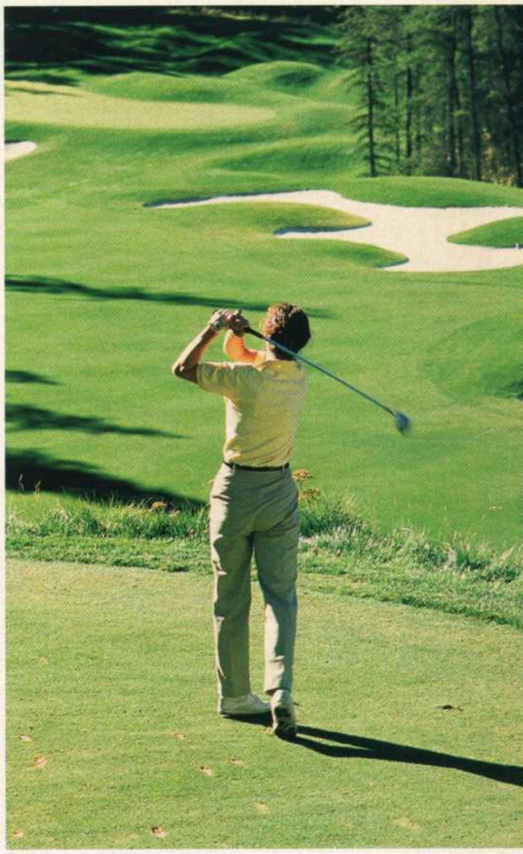
Selenium (Se) exists in soils as divalent anions, mostly selenate (SeO_4-$_2$) but also as selenite (SeO_3-$_2$), that is generally much less abundant and less readily absorbed by roots. Selenate and sulfate (SO_4-2) are chemically similar and compete for the same protein transporter for absorption into root cells. Thus, selenate is much less readily absorbed from the soil when sulfate is abundant. Although Se is an essential element for animal and human nutrition, it is not known to be required for any biochemical function in plants.

Often, the inability to identify a specific metabolic function for an element excludes it from being classified as essential.

Plants vary greatly in their ability to accumulate Se from high Se soils. Accumulator plants can contain several thousand milligrams (mg) Se per kilogram (kg) of dry tissue, and the toxic Se concentration provides protection from insect and

Continued on page 68

Granular Postemergent Broadleaf Herbicides



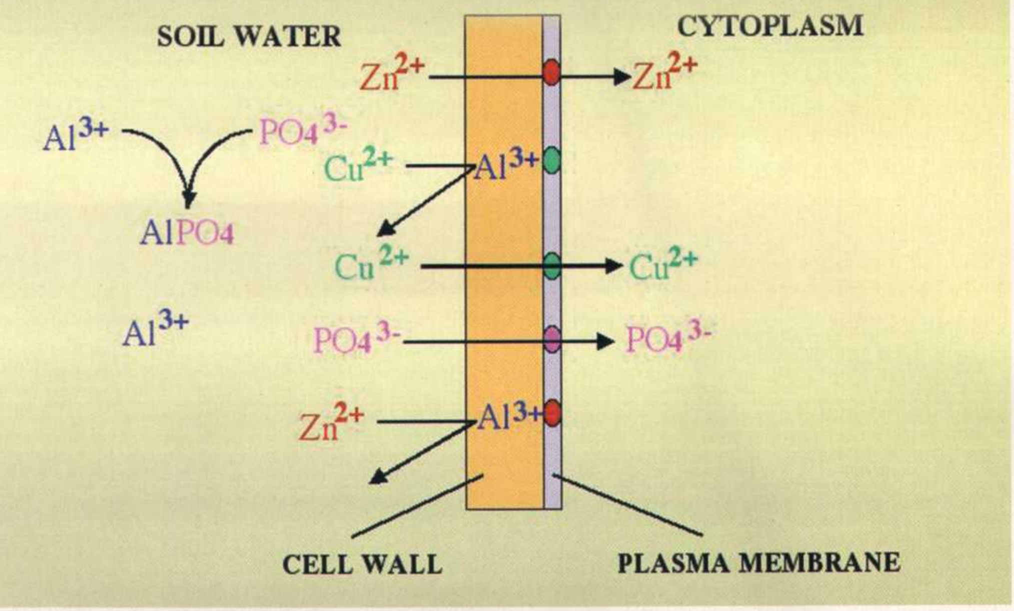
Granular postemergent herbicides from The Andersons incorporate all the latest chemistries that have been developed for postemergent weed control. Granular postemergent products are excellent for areas that are difficult to spray along with windy or wet conditions. In addition granulars are excellent for spot treating or when spraying is environmentally risky. The granular postemergent products offered by the Andersons are featured in the chart below

The Andersons ability to formulate small particle products as noted in the chart, deliver up to four times the particles per square inch compared to larger particle-size formulations (SGN240) with the same percentage of active ingredient. This in turn will provide better efficacy and a wider spectrum of weed control. Fertilizers with postemergent combination products allows turf managers to more efficiently utilize key labor resources by taking care of turf nutrition and weed pests in one operation.

Product	Active Ingredient	Key Feature & Benefits
18-5-9 with Millennium Ultra Herbicide	2,4-D Clopyralid Dicamba	■ Both foliar & root absorbed ■ Effective on wet and dry turf ■ Excellent against hard to control weeds like clover ■ Low usage rates ■ SGN150 — excellent coverage ■ Contains NS-52 slow release nitrogen
16-4-8 with Millennium Ultra Herbicide	2,4-D Clopyralid Dicamba	■ Both foliar & root absorbed ■ Effective on wet and dry turf ■ Excellent against hard to control weeds like clover ■ Low usage rates ■ SGN150 — excellent coverage ■ Contains NS-52 slow release nitrogen
21-3-20 Fertilizer Plus Dicot Weed Control III	2,4-D Mecoprop Dicamba	■ Homogenous product ■ Apply to wet turf for best results ■ Fine granules for excellent coverage and weed control ■ Contains methylene urea slow release nitrogen
20-4-10 with Trimec 20-3-3 with Trimec 22-2-4 with Trimec	2,4-D MCPP Dicamba	■ Excellent broad spectrum weed control ■ Both foliar and root absorbed ■ SGN145 for excellent weed coverage ■ Contains NS-52 slow release nitrogen
20-2-6 with 2,4-D & MCPP	2,4-D MCPP	■ Sugar grade consistency to provide maximum foliar contact ■ SGN145 for excellent weed coverage ■ Contains NS-52 slow release nitrogen
K-O-G Weed Control	Dicamba	■ Highly effective against resistant weeds like knotweed, wild onion and wild garlic ■ Label for use on bentgrass greens ■ SNG100 for excellent coverage
29-3-4 with St. Augustine Weed Control	Atrazine	■ Only combination homogenous fertilizer plus post and preemergent herbicide ■ Use on newly sprigged or established St. Augustine; Zoysiagrass; centipedegrass and carpetgrass ■ Contains methylene urea slow release fertilizer ■ SNG125 for excellent coverage

Article contributed by Darrin Johnson, Territory Manager, The Andersons Inc.

Al^{3+} can protect turfgrass roots from rapid uptake of potentially toxic ions



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animal grazing in those plants. Such plants can be troublesome for ranchers. Much of this Se is incorporated into amino acids and accumulated harmlessly (to the plant) in vacuoles.

In nonaccumulator plants, which includes most turfgrasses, the Se content is only 2 mg per 10 mg/kg dry weight. When accumulator plants are grown on a low Se medium, excessive phosphate absorption often occurs and can reach toxic levels. The addition of SeO_{4-2} reduces

There is no doubt that that cobalt, aluminum and sellenium are beneficial to a great many plants including turfgrasses.

phosphate uptake and the plant exhibits no toxic symptoms. For these plants, Se does appear to be essential.

Aluminum (Al) is highly abundant in the lithosphere and comprises about 8 percent of the earth's crust. In mineral soils, the soil solution contains less than 1 mg Al per liter when the pH is 5.5 or higher. As soil acidity increases (pH decreases below 5.5), soluble Al levels increase sharply. This greater availability of soluble Al in acid soils contributes to the failure of many plants to grow well in such soils. In short, Al is normally regarded as a toxic element and not essential for plant growth.

Some plants can accumulate Al to tissue concentrations as high as 1 millimoles or more with no toxic effects. In such plants, much of the Al is bound to organic chelates and sequestered in vacuoles. Even in these Al accumulating plants, there is no evidence that Al is essential. However, in most plants experiencing Al toxicity, Al remains in the cell walls of root epidermal and cortical cells with little entering the symplasm (interconnected living protoplasts of plant tissues) or transported to the shoots. We will consider this in greater detail in a future article on turf responses to heavy metals.

There is abundant evidence that Al at low concentrations (20 micromoles to 40 micromoles) can be beneficial to plant growth. Here the Al appears to inhibit the rapid influx of potentially toxic concentrations of phosphorus, copper or zinc, probably by forming insoluble precipitates with phosphate or impeding the movement of metal cations through channels in the plasma membranes of root cells.

Turfgrasses generally experience inhibited root growth in acid soils because of elevated Al concentrations. However, considerable variation in sensitivity to Al has been observed among turfgrass species and among cultivars of some species (Liu et al., 1997a). Fine fescue was found to be considerably more tolerant of high Al levels than perennial ryegrass, tall fescue or Kentucky bluegrass. Among the bentgrasses, colonial bentgrasses were more Al tolerant than most creeping bentgrass cultivars, but there was considerable variation in Al tolerance among these cultivars (Liu et al., 1997b).

Other elements that have been reported to be beneficial to plant growth include iodine, vanadium, titanium, lanthanum and cerium (Marschner, 1995). Such reports are often confined to a few species or have not been confirmed in controlled experiments. Obviously, a good amount of further research on this subject can be justified. However, there is no doubt that the two common elements, sodium and silicon, are beneficial to a great many plants including turfgrasses. In future articles, we will consider these elements in greater detail.

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Bridging the Biostimulant Gap

The heated debate over efficacy may finally be reaching the end

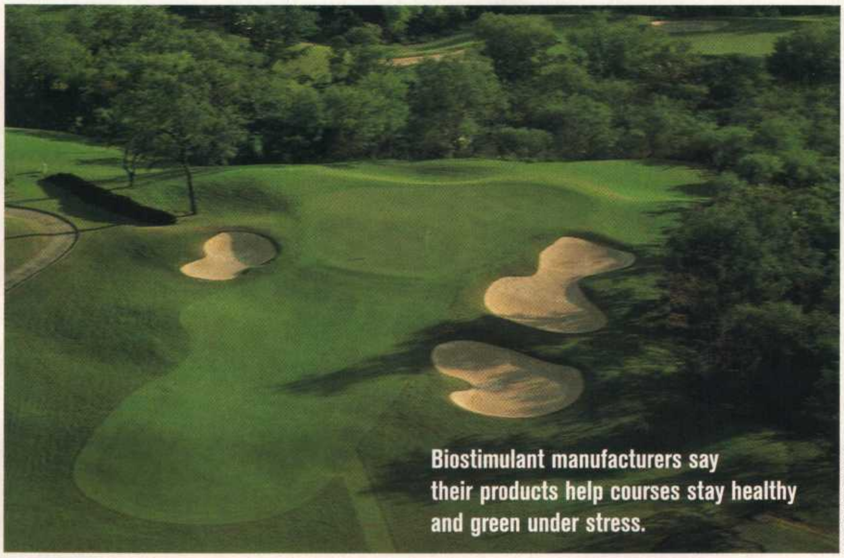
By Frank H. Andorka Jr.
Managing Editor

For more than 10 years, Keith Karnok has asked questions about biostimulant use by superintendents. The turfgrass professor at the University of Georgia did it again in February at the GCSAA Conference and Show in San Diego, telling superintendents, "We cannot shortcut the time-proven, research-based principles of turfgrass management [by using biostimulants]."

While Karnok stands by those sentiments and amplifies them often in frequent presentations to superintendents' groups, he always gets the same question at some point: Would he use biostimulants if he were a superintendent?

"The answer is a qualified, 'yes,' " Karnok admits. "If I had fine-tuned my fertility program and felt completely comfortable with my agronomic plan, then I'd ask the manufacturers to see their research and do some test plots on the course to see if the products do what they say they're going to do. Then, if I had money left over in my budget, I'd consider them."

Karnok's admission shows how far biostimulants have come in the industry. Five years ago, some superintendents viewed biostimulants with suspicion, thanks to slick salespeople who oversold the products as a cure for all turf problems. Now with more research to back up toned-down claims, many superintendents use them as a regular part of their maintenance programs. In fact, Bob Weltzein, marketing manager for the Roots Plant Care Group of Novozymes/Roots, groans when he hears *Golfdom* is doing an updated article on the debate.



Biostimulant manufacturers say their products help courses stay healthy and green under stress.

MIKE KLEMME

"It's really over," Weltzein says. "There is hardly a superintendent out there anymore who doesn't use them in some form or another."

Well, it's not *quite* over. Researchers like Karnok and others still wonder how well biostimulants perform under real-world conditions, while manufacturers fire back that the current research is conclusive enough. But given the acrimony over the past decade, the two sides of the biostimulant debate are closer together than ever before, and the eventual end of the battle may be in sight.

What is a biostimulant?

Bert McCarty, professor of agronomy at Clemson University and author of the 2001 book *Best Golf Course Management Practices*, writes that the term biostimulant is "an ambiguous term used to encompass non-nutritional growth-promoting substances such as microbes, plant growth hormones, soil conditioners and microbe energy sources." McCarty's definition is certainly comprehensive, but it may be *too* comprehensive when it comes to evaluating commercially available biostimulants because few are strictly non-nutritional.

Karnok says most biostimulant products contain some combination of the following ingredients: plant hormones, microbes, humates, mycorrhizzae, and/or vitamins/enzymes. The problem is most biostimulants also include some nutritional components, which troubles academics like Jack Fry, a professor of turfgrass management at Kansas State University.

"You can't just test the products the companies give you," Fry says. "You have to separate the purported active ingredi-

Continued on page 72