TABLE 2

Three classes of silicon absorbers: Si accumulator (rice), Si nonaccumulator (wheat) and Si excluder (soybean). Plotted from data of Vorm (1980) as presented in Marschner (1995).

Silicon sources used to augment soil Si or include Si in nutrient solutions.

Si source	Chemical formula	Si content	Use*%
Salicic acid	H4SiO4	29	None
Calcium silicate slag	CaAl2Si2O8	18-21	SM
Calcium silicate	CaSiO3	24	SM & NS
Potassium silicate	K2SiO3	18	NS
Sodium silicate	Na2SiO3	23	NS
Quartz sand (fine grind)	SiO2	46	SM

* SM = soil or solid medium; NS = nutrient solution; None = research use

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Because the structural effects of Si deposits require time to establish, it is questionable if frequently mowed turfgrasses would ever show greater Si-induced wear tolerance. Earlier studies demonstrated a decreased decomposition rate of Si-enriched turfgrass (tall fescue and Kentucky bluegrass) tissues incorporated in soil. This suggests that high Si levels in turfgrass shoots could slow the degradation of thatch and promote its accumulation.

To see the full text and charts of Dr. Hull's article, please go to: *www.turfgrasstrends.com.*

Si and disease resistance

The Si content of plant tissues has been positively correlated with enhanced resistance to soilborne and foliar diseases (Datnoff et al. 2001). A research team in Florida headed by Lawrence Datnoff demonstrated the effectiveness of Si enrichment in controlling several diseases of warm-season turfgrasses. About 30 percent of gray leaf spot on St. Augustinegrass was controlled by Si applications, and its addition increased the effectiveness of fungicide treatments (Brecht et al. 2001).

Common bermudagrass exhibited a doubling of its Si content when its growth medium was supplemented with calcium silicate (Datnoff and Rutherford, 2003). Leaf spot caused by *Bipolaris cynodontis* was suppressed about 40 percent in the high Si bermudagrass. This study demonstrated that the media used for greens construction are often low in plant available Si and the addition of this element can increase the Si content of bermudagrass turf and enhance its disease tolerance.

Studies of Si and disease resistance in cool-season turfgrasses have been less extensive but the results are similar. Tremblay et al. (2002) reported that under greenhouse and field conditions in Quebec, the addition of soluble Si to fertilizer significantly reduced dollar-spot injury on creeping bentgrass.

Hamel and Heckman (1999) at Rutgers University reported on greenhouse experiments in which Kentucky bluegrass sod plugs were grown on artificial media or native soil supplemented with several Si sources. They observed that the addition of Si to the artificial potting mix reduced powdery mildew with reasonable consistently, while these materials exhibited less consistent disease suppression when applied to the mineral soil. No Si analyses of plant tissues were reported.

While existing research on Si and disease suppression has hardly considered all turfgrasses or even many turf diseases, the results to date strongly suggest that insuring favorable Si status of turf will enhance its disease tolerance. The impact of Si on strengthening plant cell walls and stabilizing lignin formation provides a sound theoretical basis for plant disease suppression. Some of this research also indicates that current turf cultural practices may be producing turf low in Si and thereby less fit to tolerate a range of stress conditions.

Conclusions

Of all the beneficial plant nutrients, Si clearly has the greatest potential for being useful as a turfgrass management tool. Si's abundance in most soils can give the erroneous impression that it doesn't need to be supplemented in fertilizer. Heavily leached acid soils may be unable to restore silicic acid to the soil solution when it is being absorbed by vigorous plant growth.

The evidence available clearly suggests that supplying Si to turfgrasses may reduce water use by retarding cuticular transpiration, produce more erect plant growth (thereby increasing photosynthetic efficiency), promote a cleaner cut during mowing (thereby favoring more rapid regrowth), retard pathogen attacks by providing tissues less suitable for disease establishment and resist insect feeding due to the presence of less-digestible, toxic vegetation.

Silicon is certainly a potential cultural tool that the turf manager might want to consider seriously.

Hull, professor emeritus at University of Rhode Island in Kingston, can be reached at rhull@uri.edu.

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TURFGRASS TRENDS

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Improvement Detected in Moisture Sensors

Irrigation companies are still skeptical about short-term impact of the technology but see future uses growing

By PETER BLAIS

Considered unreliable, inaccurate and too expensive for golf courses for many years, soil-moisture sensors have made huge technological strides recently in all these areas. They are becoming more appealing as a way to help determine irrigation needs for golf courses at a time of growing water shortages.

"It's not a matter of if, but a matter of when," says Dana Lonn, director of the Center for Advanced Turf Technology, with The Toro Co. "From an R&D standpoint, we are monitoring what is happening and evaluating some of the commercially available sensors. We have found them to be quite useful. We haven't actually put anything into product yet, but it's just a matter of time."

The golf industry has long used weather station-based sensors placed above ground to determine irrigation needs. These sensors measure solar, humidity, temperature, wind, dew point and rainfall factors that combine to determine an evapotranspiration (ET) rate. Controllers use the ET information to determine the amount of water loss and how much water should be used to irrigate. Most large, commercial watering systems sold by companies like The Toro Co., Rain Bird and Hunter Irrigation are ET-based, according to Mike Miller, manager of Baseline LLC, which markets soil-moisture sensor-based irrigation control systems.

Miller believes in-ground, soil-moisture sensors are more accurate indicators of water loss than above-ground ET systems because they measure how much water is lost in the soil. In the past 30 years, companies developed all types of soil-moisture sensors, but they didn't work particularly well. However, recent sensor technology that measures the speed of light as it passes through the soil is much more accurate and reliable in determining soil-moisture content than its predecessors, Miller says.

"The golf industry is slowly warming to the idea that soil sensors truly do work," Miller says. "Over the next five to 10 years, we will see a transition from above-ground sensors to in-ground sensors."

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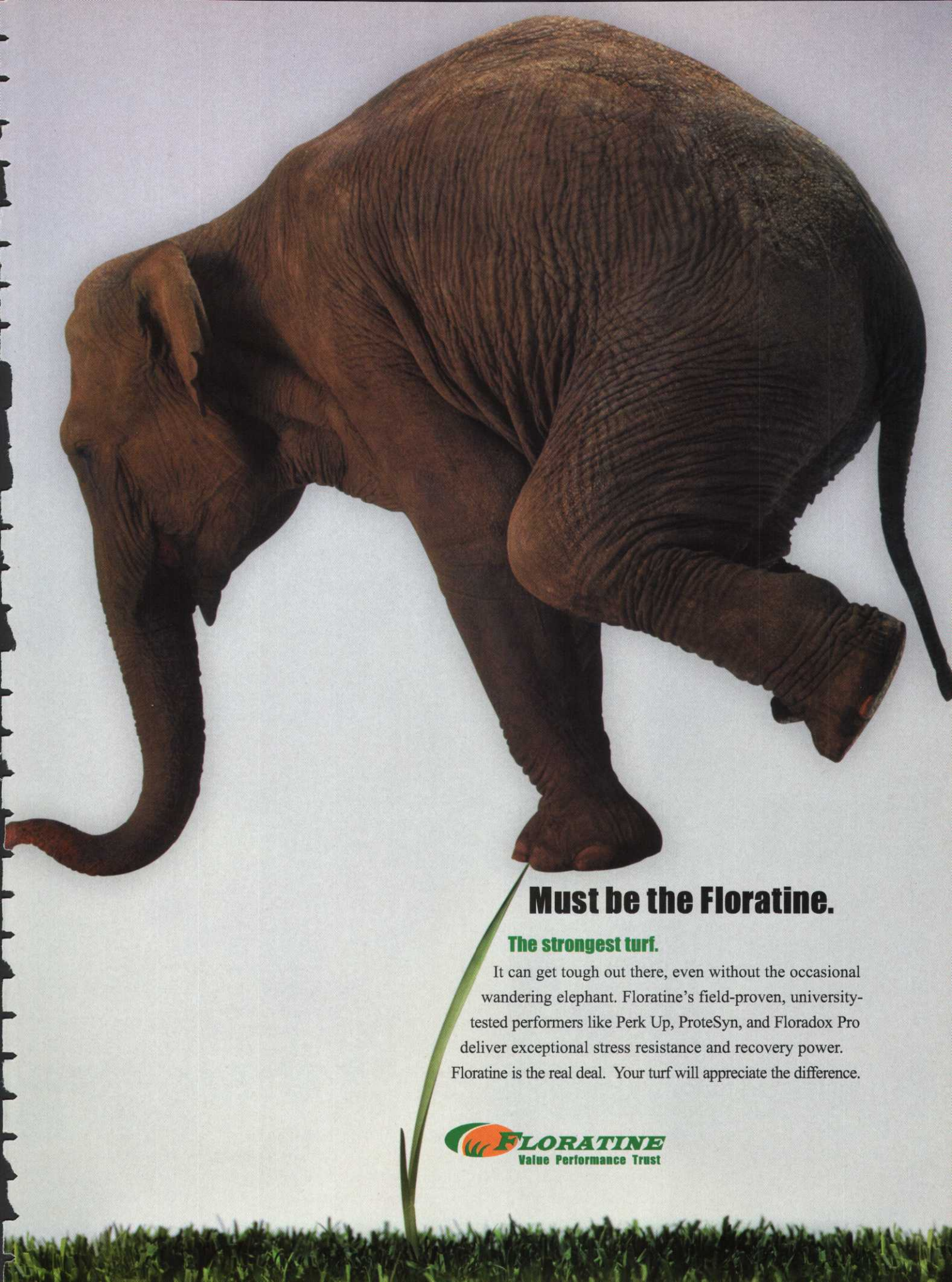
Soil moisture sensors like this one have made huge technological advances since their early days, when they were considered expensive, unreliable and inaccurate.

PHOTOS COURTESY OF BASELINE LLC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According to the Irrigation Association, soil moisture sensors can save an average of 15 percent to 30 percent of water used.

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ET will save an average of 5 percent to 15 percent in water use, Miller says. Soil-moisture sensors will save an average of 15 percent to 30 percent of water, according to the Irrigation Association.

Acclima is a commercial provider of sensor-based, irrigation-control technology that relies on soil-moisture levels.

"We have not pursued the golf market at all," says Scott Anderson, Acclima's president. "Sensors, however, would be suitable for golf once we get our controller support to the level where we can handle large applications."

One golf company that has already made a major investment in soil-moisture sensor technology is Signature Control Systems, according to Drew Ferraro, the company's marketing manager. Soil-moisture sensors are connected directly to Signature's field satellites, which use patented technology called peer-to-peer communication, allowing all the satellites on a golf course to share information rather than relaying the information through a central computer.

"The satellites then use that information to adjust irrigation on the golf course," Ferraro says. "The satellites can also radio that information to other satellites."

For instance, instead of having 18 moisture sensors on 18 different greens, a superintendent could determine green No. 6 is fairly representative of other greens in full sun, while the 16th green represents other greens in partial or full shade. A moisture sensor placed on No. 6 could be wired to the satellite on that hole. That satellite could then radio moisture information to Nos. 2, 4, 8, 12, 18 and the practice putting green because they have sunny surfaces like No. 6. Then the controllers could automatically make irrigation adjustments.

Likewise, a moisture sensor wired to the satellite on shady No. 16 could radio that information to other shady greens.

Signature Controls also makes controllers for Advanced Aeration Systems, a designer and manufacturer of subsurface aeration systems, Ferraro says. Advanced Aeration uses moisture sensors, and improved sensors will soon hit the market, according to Dave McIntosh, a turfgrass consultant with Advanced Aeration.

"Moisture sensors tell you exactly what is going on in the soil," McIntosh says. "In my experience, most weather stations are either nonfunctional or in areas that are not representative of a golf green. The data they gather to help with ET is at best haphazard or not specifically tailored for particular microclimates. With sensors, on the other hand, we can put them in specific locations around the course. Then we have a weather station capable of telling us what the microclimate of a specific spot is."

While acknowledging soil-moisture sensor technology is improving, major golf irrigation companies like Rain Bird and Toro are not about to cast their ET systems aside.

Rain Bird product managers Randy Mills and Bruno Quanquin note that although the company has the ability to use moisture sensors with its central-control systems, it is not currently doing so.

"We have not been involved in use of sensors in the past because it has proven difficult to find reliable sensors," Mills and Quanquin

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"It's not a matter of if, but a matter of when [soil-moisture sensors will become standard on irrigation systems]."

DANA LONN

THE TORO CO.

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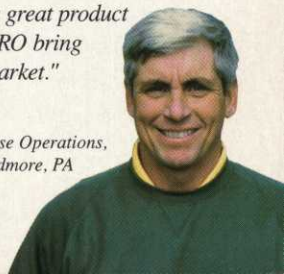

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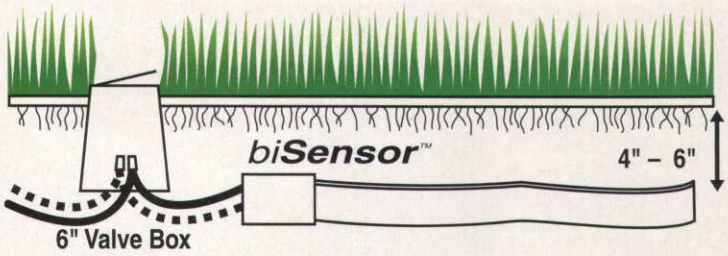

In the system pictured above from Baseline LLC, two wires send information back to a central controller, which determines whether the turf needs water and manipulates the irrigation system accordingly.

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explain. "End users have been disappointed in the past by the poor results. An inexpensive, accurate and reliable sensor would be successful in golf if there was one."

They also believe ET-based systems are likely to continue as the standard way to determine water needs for the foreseeable future.

"Soil-moisture sensors give us soil-moisture information about a specific point in the soil profile," Mills and Quanquin say. "While there are methods to use moisture sensors for irrigation in agriculture, turf and golf applications have not tended to use them. ET from a weather station is a more general value and can be approximated throughout the golf course using some simple yet accurate methods."

Toro's Lonn agrees that soil-moisture sensors are an emerging technology, noting their use in primarily specialty crop agriculture. Those who have tried them in the golf business generally found they didn't work well, he says.

"But the technology has improved a lot," he adds. "People use different principles to measure soil moisture."

According to Lonn, the best approach for predicting water need is combining evapotranspiration with moisture sensors, which together give both an estimate of the environmental load along with measuring moisture in the soil. Indeed, Lonn believes irrigation's future is in a combination of ET and soil-moisture sensor technologies.

"The important point is that the whole water conservation issue is moving higher on everyone's radar screen," he says. ■

Blais is a freelance writer from Monmouth, Maine.

Essayist Tackles Water Conservation

Editor's note: Margaret Anna Bolick won the Aquatrols & Golfdom Essay Contest and received a $2,000 scholarship for her winning essay, "Water Conservation in Turf and Landscape." Jaron Andrews and Cathryn Arruda finished second and received $1,000 scholarships. Bolick, who will attend Lander University in Greenwood, S.C., later this year, is the daughter of Marion P. Bolick, grounds superintendent at Lexington Medical Center in West Columbia, S.C. Below is an excerpt from Bolick's winning essay.

Through design, technology and education, we can ensure that our most precious natural resource will be available for generations to come through water conservation.

Design is an important factor in creating a water-efficient landscape, and xeriscaping designs reduce water requirements (Knox, 1). The term xeriscaping combines the Greek word "xeros" meaning dry and landscaping (Lang, 1). Xeriscaping includes several important elements, including planning and design; soil analysis; turf areas; plant selection; efficient irrigation; mulches; and appropriate maintenance (Duble, 1).

As with any landscape design, designers should become familiar with existing land and plant materials. Knowing the budget, water availability and maintenance requirements are also important factors. A vital element in xeriscaping is to group plants according to their water, soil and sunlight needs ("Landscape Cary Style"). In xeriscaping, plants with similar water requirements should be grouped together in zones (called hydrozones) so each group receives only the amount of water required to maintain the plant. (Knox, 2). An efficient irrigation system should be an integral part of any xeriscape.

It's also important to analyze soil before planting. Adding organic matter to soil also improves its structure; reduces runoff and flooding, improves fertility; attracts earthworms and other beneficial organisms; and reduces stress on plants caused by drought, heat and cold ("Landscape Cary Style").

Turf offers an important aesthetic value to the landscape design but should not be overused because of its increased water and maintenance requirements. An important aspect of xeriscaping is to use drought-tolerant varieties of turf where possible.

Proper spacing of sprinklers is critical in achieving uniform water application. Sprinklers spaced too far apart will waste water by applying too much water in some areas and not enough in others. Spacing sprinklers closer than required increases the cost of the system and wastes water (Bilderback, "Efficient Irrigation 2").

Mulch conserves water by providing a cover over the soil, reducing evaporation, soil temperature and erosion. It also limits weed growth and competition for water and nutrients (Smith, "Landscape Water Conservation 2") while adding nutrients to the soil as they decompose.

Desert courses are removing turf areas to deal with water restrictions.

MIKE KLEMME

Next, water conservationists have learned how to achieve their aims in the green industry with the help of technology. Chemical surfactants lower water-use rates by improving root zones, preventing localized dry spots, avoiding moisture stress and enhancing performance of chemicals. (Usage Guides: Turf Products 1). Advancements in irrigation clocks have enabled wider control and flexibility in programming the irrigation system. Computerized irrigation systems, used mainly on larger landscapes and golf courses, offer maximum control.

Communities throughout the country are faced with increased demands on existing water supplies. Consequently, there is a greater focus on water conservation. It is left to each one of us not to take this most precious natural resource for granted any longer but to conserve it to ensure a bountiful supply for years to come. ■

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