Bolster Turf's Ability to Use Natural Defenses Against Stress

The key is managing rootzone moisture conditions

By Erik H. Ervin

Several years of research at Virginia Tech indicate that improving certain rootzone environment conditions, particularly overcoming water repellency and providing consistent water availability, enhanced turf ability to avoid drought stress resulting in more efficient photosynthesis and greater up-regulation of defenses for tolerating stress.

Photosynthesis can be said to be the basic plant process — producing the chemical energy (carbohydrates) required for all growth and maintenance processes. Anything that interferes with efficient photosynthesis will reduce turf health and ability to deal with stress; anything that favors efficient photosynthesis will bolster turf's health and ability to withstand and defend itself against stress. Growing conditions in the rootzone have a significant impact on the level of photosynthetic efficiency that a plant can achieve.

Two stress-related dynamics in plant physiology are the production of free radicals and antioxidants. Free radicals disrupt key plant functions, and one of the key roles of antioxidants is to "deactivate" or "neutralize" these free radicals.

Production of free radicals occurs even under optimum conditions, but it is significantly higher when conditions for photosynthesis are suboptimal. Production of antioxidants is natural, but it can be hindered when carbohydrate reserves are low or rootzone conditions are unfavorable. This is also related to how efficient photosynthesis has been. It is clear that rootzone conditions affect both stress occurrence and turf's ability to defend itself against that stress.

To understand all this further, and the impact of cultural practices affecting the rootzone environment, it might help to review the complex machinery of the plant.

Plants consist of millions of cells, each of which contains organelles. Each type of organelle has a specific function. For example, chloroplasts capture light energy; the nucleus directs growth, and mitochondria respire energy to fuel growth. All cells and their organelles are suspended within a water-based solution and are bounded by membranes. The membranes provide structural integrity while allowing substances to diffuse in and out as required for efficient growth and maintenance.

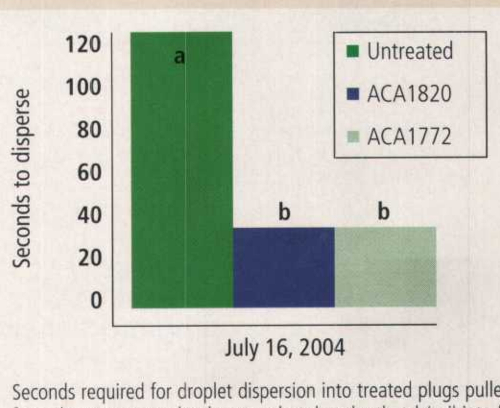
Chloroplast membranes contain light-harvesting green pigments called chlorophyll. There are two types of chlorophyll designated as chlorophyll-a and chlorophyll-b. In full sun, chlorophyll-a outnumbers chlorophyll-b by three to one. Chlorophyll forms complexes with proteins in the chloroplast's membranes called photosystems. The photosystems capture light energy and turn it into chemical energy.

Here's how it works. Light hits a chlorophyll-a molecule and causes an electron within the chlorophyll molecule to go to a higher energy level. The energy from these excited electrons is then used to split water from the soil and release more electrons. These electrons are then transferred through the protein-based photosystems to produce energy in the form of NADPH (nicotinamide adenine dinucleotide phosphate) and ATP (adenosine tri-phosphate). The plant uses this as energy to drive carbon dioxide (CO_2) fixation and produce carbohydrates.

Some key ingredients for this process to occur include light, oxygen, water and nutrients from the soil. The consistency or inconsistency of supply of all of these has a direct impact on the levels of photosynthesis that will be able to take place.

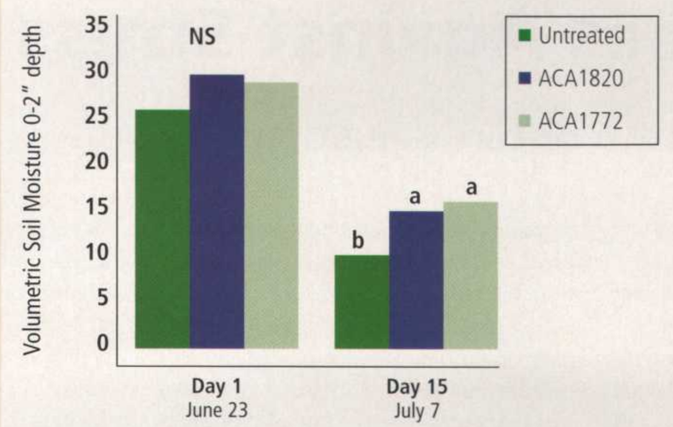
Continued on page 60

TABLE 1



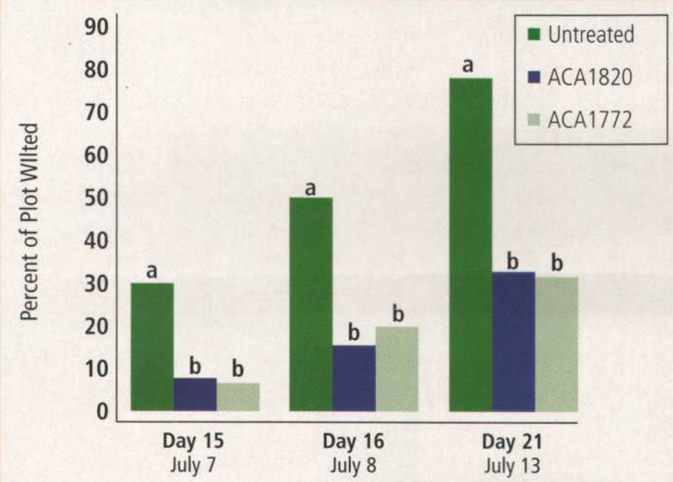
Seconds required for droplet dispersion into treated plugs pulled from the test green; droplet was placed at the thatch/soil interface. Irrigation was withheld over a 21-day period in 2004. Treatments were initiated on June 16. Bars labeled with different **a** or **b** letters are significantly different at a 95% probability level.

TABLE 2



Effect of a surfactant on 0-2" depth volumetric soil moisture content as irrigation was withheld over a 15-day period in 2004. Treatments were initiated on June 16. **NS**=no significant difference. Different **a** or **b** letters are significantly different with 95% probability.

TABLE 3



Percent of plot wilted as irrigation was withheld over a 21-day period in 2004. Treatments were initiated on June 16. Bars labeled with different **a** or **b** letters are significantly different at a 95% probability level.

Continued from page 59

Turf coping mechanisms

Even under optimum temperature, light, and moisture conditions there is waste in the system resulting in inefficiencies and the production of free radicals in chloroplast photosystems. Similar to a car engine, there are a number of toxic chemical emissions or byproducts of photosystem function that the plant must deal with to remain healthy. Under less than optimal temperature, light and moisture conditions, the inefficiencies will be greater.

Why do these inefficiencies occur? Photosystems of plants that are completely dependent on a C3 (or Calvin-cycle) photosynthetic pathway are not immediately capable of using all the excited electrons that are created when chlorophyll electrons are excited by light. Generally, this inefficiency is due to the inability of the enzyme Rubisco to fix enough CO_2 to utilize all of the available light for carbohydrate production. Although Rubisco preferentially fixes CO_2, it also fixes O_2 in a process called photorespiration. As temperatures build and stomates narrow in response to limited soil moisture, the internal concentration of O_2 increases relative to that of CO_2, increasing photorespiration and the inefficiency of light capture. The unused excited electrons are either lost directly as heat or as a light emission called chlorophyll fluorescence — or they react with "good" (ground state) oxygen (chemically represented as $^3O_2$) and form free radicals such as "bad" singlet oxygen ($^1O_2$), the superoxide radical ($^XO_{2-}$), and hydrogen peroxide (H_2O_2).

Chlorophyll fluorescence is a natural phenomenon that is measured easily on turfgrass canopies with a chlorophyll fluorometer and converted to a standard measure in plant physiology called photochemical efficiency. Briefly, the more light being given off (or fluoresced) from the canopy, the less efficiently that light energy is being used by the photosystems to run the photosynthetic reactions and produce carbohydrates. Optimized turfgrass canopies have photochemical efficiencies of about 0.7, while those under stress are at 0.55 or below.

Free radicals, if not quickly converted to water and ground-state oxygen by antioxidants, damage proteins and DNA, bleach chlorophyll, and disrupt membrane integrity. Left unchecked, free radicals can lead to plant death.

To address these inefficiencies, the plant has various natural coping and defense mechanisms. To deal with the free radicals, healthy plants have a robust defense system that produces antioxidants to "deactivate" or "neutralize" the damaging free radicals. Three of the

Continued on page 62

Continued from page 60

most common (and important) antioxidants that make up this defense system are the enzymes superoxide dismutase (SOD), ascorbate peroxidase (APX), and catalase.

This defense system also requires favorable conditions to operate efficiently and can be overwhelmed by stress. Stresses such as drought and heat increase the production of free radicals. And if the plant has low energy reserves, poor access to soil moisture or damaged root systems, then it will often lack the ability to increase production of enough antioxidants (which are nitrogen and carbon-rich proteins) to offset the increase in free radicals. The result is called oxidative stress — a primary factor in summer bentgrass decline.

Managing rootzone moisture

With soil moisture being a significant factor for both photosynthesis and the operation of turf's natural defense systems, the question was raised regarding the impact that modifying soil moisture might have on these plant functions. Since the occurrence of water repellency and non-uniform rootzone wetting can interfere with consistent moisture availability required for optimal plant functioning, our research hypothesis was that use of surfactants to correct water repellency and provide more consistent availability of moisture would enhance plant performance. A research project was initiated to investigate this hypothesis.

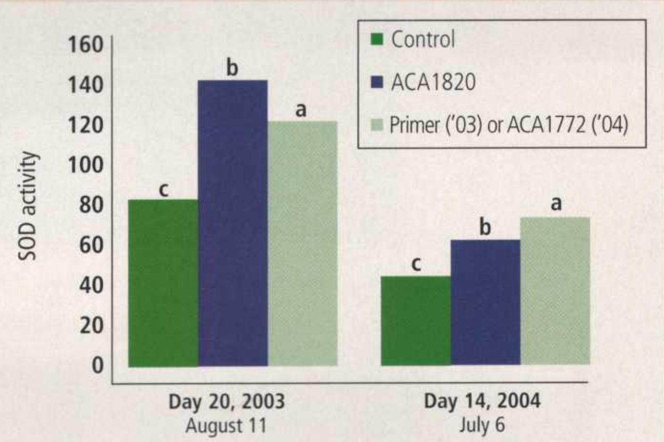
Previous research on a new patent-pending methyl-capped surfactant formulation (ACA1820, commercialized as Revolution) indicated that this particular formulation contributed to turf being able to better withstand stresses and maintain higher quality ratings compared to turf managed with other surfactants already on the market. The manufacturer's hypothesized that because of its unique structure, this material would not just overcome water repellency, but could improve the rootzone moisture and air environment to a degree that would positively influence the turf's physiological functions. Such a claim had not been made previously on behalf of a soil surfactant, and the company was willing to fund research to investigate its hypothesis.

The test area was a 35-year old sand-modified bentgrass/*Poa* green with a significant organic matter layer (4.4 percent) and water repellency (Table 1, p. 59), which regularly exhibited localized dry spots. There was about 40 percent to 60 percent *Poa* within the bentgrass stand. The area was mowed four times per week at 0.125 inches and received standard fertility and fungicide applications every two weeks. In June through September of 2003 and 2004, ACA1820 was applied monthly at 6 ounces/1,000 square feet, while Primer Select was applied monthly at 4 ounces per 1,000 square feet in 2003 only, and ACA1772 was applied at 8 ounces per 1,000 square feet at trial initiation and then seven days later in 2004 only.

Trials in 2003 focused on collecting biochemical measures of the physiological health of turfgrass leaves and turf-quality ratings

Continued on page 64

TABLE 4



Superoxide dismutase (SOD) antioxidant enzyme activity of leaf tissue as affected by surfactant treatment as irrigation was withheld during summers of 2003 and 2004. Days 20 or 14 refer to the number of days into a drought cycle where no significant rainfall has occurred, with the corresponding sample date included below. Bars labeled with different **a**, **b** or **c** letters are significantly different at a 95% probability level.

Continued from page 62

through a stress period. In particular, activity levels of key antioxidants, levels of the amino acid and osmoregulant-proline, chlorophyll levels and photochemical efficiency were monitored. July and August of 2003 provided heat and drought conditions that imposed stress resulting in wilt and turf decline.

Trials in 2004 included a three-week dry-down period between June 21 and July 13. Additional data collected included visual wilt ratings, clipping weight, soil moisture levels and water droplet penetration time.

Relative to the untreated control, we measured greater retention of available soil water (0-2 inch depth) during non-irrigated dry-down cycles (Table 2, p. 60) and significantly less leaf wilting (Table 3, p. 60) due to both surfactant treatments. Less wilting was accompanied by higher antioxidant levels (Table 4, p. 62) resulting in the maintenance of higher chlorophyll levels and canopy photochemical efficiency.

We also measured increased leaf tissue levels of proline, in ACA1820 and Primer Select plots in 2003 and only due to ACA1820 in 2004. A natural mechanism of most plants experiencing declining soil moisture availability is to alter energy use dynamics in favor of proline accumulation. Proline increases of one to tenfold have been commonly measured in response to moderate drought stress. Increased proline serves to concentrate the cell solution, protect protein function, and delay cell dehydration. The effect is longer maintenance of leaf turgor (and photosynthesis) under mild to medium drought stress.

Ultimately, turf quality is the measure of success for turf management programs and cultural practices. In both 2003 and 2004, turf quality in the treated plots was significantly higher and showed less susceptibility to stress conditions (See additional figures and charts at turfgrasstrends.com).

Summary

As noted at the start, healthy turf begins with efficient photosynthesis. The availability of a good balance of moisture and oxygen in the rootzone are key factors in how efficient photosynthesis can be. Our research indicates that surfactant formulations have a positive impact on these rootzone conditions and a correspondingly positive impact on photochemical efficiency, level of antioxidant production and other drought stress-related plant functions.

Turf areas treated with such surfactants showed an enhanced ability to avoid drought stress resulting in more efficient photosynthesis and greater up-regulation of defenses for tolerating stress. Research is ongoing to investigate and better understand differences in the effects and consistency measured with different surfactant formulations.

The final implication for the superintendent from bolstering turf's ability to use natural defenses against stress is the possibility of healthier greens that stay healthier, because they can sustain photosynthetic integrity longer during drought events, experience less oxidative stress and recover/respond faster at each irrigation event.

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Author Erik H. Ervin, Ph.D., is an associate professor of turfgrass physiology in the Department of Crop and Soil Environmental Sciences at Virginia Polytechnic Institute and State University.

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SECTION STAFF

Managing Editor
Curt Harler
440-238-4556; 440-238-4116 (fax)
curt@curtharler.com

Graphic Designer
Kristen Morabito
216-706-3776; 216-706-3712 (fax)
kmorabito@questex.com

Golfdom Staff Contact
David Frabotta
216-706-3758; 216-706-3712 (fax)
dfrabotta@questex.com

CONTACT US:

Web site: *www.turfgrasstrends.com*
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