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TURFGRASS TRENDS

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TURFGRASS STRESS

Multispectral Radiometry:
Opportunities for detecting stress in turfgrass

By Elizabeth Guertal, Joey Shaw and Dave Han

The words "stressed turfgrass" quickly bring a picture to the mind of any turfgrass manager. Stressed turf is off-color, wilted, thin, patchy or straggly. It is easy to see the turf is not healthy, even if it is often difficult to tell why it is stressed.

But what if you could identify areas of stressed turfgrass before that stress is visible to the eye? Pinpointing areas that are under stress very early on could allow a turfgrass manager to apply management techniques to correct the stress before the problem becomes visible or widespread. Early detection and correction of stressed areas would maintain the turf's quality and could lead to reduced pesticide, water or fertilizer use, as spot-sprays or treatments could be applied only when and where they are needed.

Using remote sensing methods

A method currently being explored in turfgrass science for early detection of stress is remote sensing via multispectral radiometry. Radiometry measures the amount of energy reflected and emitted from plants. Multispectral radiometry measures reflectance over a range of many wavelengths.

Using a device known as a radiometer, researchers are currently testing whether the light reflected from turfgrass at a variety of wavelengths can predict stress. Currently, researchers mostly are testing handheld radiometers (Figure 2), but the real promise of multispectral radiometry comes when the radiometers are mounted in aircraft, which can then fly over entire golf courses, remotely sensing turfgrass stress from the air. This could allow managers to make a 'stress map' of their turf, enabling them to identify and correct stress before it becomes visible at ground level.

Currently, turfgrass researchers are trying to accomplish two things with remote sensing of turfgrass stress. First, they are trying to see how well the radiometer readings correlate with visual observations of turfgrass stress from a variety of sources (disease, drought, compaction etc.). Second, they are trying to determine which wavelengths of energy are best for detecting stress and whether the wavelength(s) that best detect stress change with the type of stress, the type of grass or time of year.

For a turfgrass manager to use a radiometer to reliably detect stress, he or she must know the wavelength to use and if the measurement is consistent over a range of grasses and environments.

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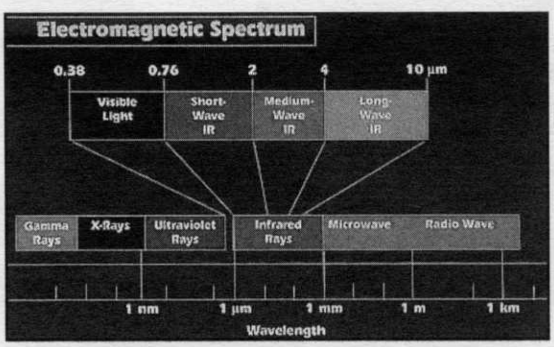
Measuring disease stress

One area of turfgrass science where early detection of stress is critical is in plant disease. Here, early detection can save major headaches later on. When remote sensing of Rhizoctonia blight and gray leaf spot in tall fescue was studied, reflectance at the 810-nm (NIR) wavelength was best correlated with visual estimates of disease severity (Green et al., 1998).

Typically, the percent reflectance of NIR wavelengths will decrease as plant stress increases. However, there was large variability in the reflectance values — almost twice as much as the variability in visual disease ratings. This is probably due to the fact that factors other than plant disease affect reflectance ratings, and a machine can't tell the difference between disease stress and other stress as well as a trained human.

The variability in NIR reflectance readings means that, in effect, the radiometer must be calibrated every time it is used. Because of this, radiometers are most useful for detecting differences in disease at a specific time.



What if you could identify areas of stressed turfgrass before that stress is visible to the eye?

Radiometers are less useful for monitoring disease development, as it is difficult to compare one days' reading to the next (Raikes and Burpee, 1998).

Other researchers found that radiometer readings at the visible (VIS) wavelength of 661-nm and the NIR wavelength of 813-nm were best correlated with visual estimates of turfgrass quality (Trenholm et al., 1999). When a radiometer was used on bermudagrass that had received five different levels of soil compaction, the readings at 681-nm (VIS) best correlated with soil penetrometer readings of compaction (Guertal et al., 1999; Shaw et al., 1999).

While radiometers can detect stress, radiometer readings alone can not determine the source of that stress.

It appears that regardless of the stress imposed on the turfgrass, differences in radiometer values are best expressed in the 600-815-nm wavelength range. This covers red visible light and shorter wavelengths in the NIR range (Figure 1).

Although most research is performed with hand-held radiometers, these units are too expensive and their use too time consuming to be of much practical use for most turf managers. The key to effectively using multispectral radiometry is to couple it with aerial remote sensing. Preliminary work here at Auburn University has shown good agreement between readings collected from hand-held radiometers and those collected from an aircraft-mounted radiometer. There are commercial firms that conduct fly-overs of turfgrass and supply pictures that delineate areas of stressed turf as measured by energy reflectance at specific wavelengths.

In summary, research has shown that multispectral radiometers are useful for detecting turfgrass stress. The radiometers work well when specific treatments are applied to research plots and readings taken at the same time are compared to each other. However, comparing the readings across time has not been as successful because the research has shown that there is a great deal of variability in readings from one time to the next. Another limitation to

the use of multispectral radiometry is that we still know very little about variability in readings due to grass species, cultivar or many of the soil variables that affect turfgrass stress.

Finally, major limitation of multispectral radiometry is that while radiometers can detect stress, radiometer readings alone can not determine the source of that stress. Research has shown that the best wavelengths for detecting many turfgrass stresses are the same, regardless of the type of stress (whether it is disease, compaction or drought).

For example, at Auburn we found that the wavelength at which we best detected turfgrass stress due to compaction was the same wavelength at which we detected stress due to nitrogen deficiency. So, even though an aerial-remote sensing data may show areas of stressed turf, in the end there is no substitute for the human eye and brain. A turf manager will still need to use experience and additional diagnostic tools to identify the source of the stress.

— Elizabeth Guertal is Alumni associate professor of turfgrass soil fertility; Joey Shaw is assistant professor, soil morphology; and Dave Han is assistant professor and extension specialist in turfgrass management at Auburn University, Auburn, AL.

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Probing Turfgrass Irrigation Saving Strategies for the 21st Century

By F. C. Waltz and L. B. McCarty

As water conservation and usage become more important issues, golf course superintendents and other turf managers will be forced to make more judicious use of water resources. Turfgrass managers will have to justify the use and volume of water and forgo the days of indiscriminate irrigation.

Since the soil in the rootzone acts as a storage reserve for water, an understanding of the soil moisture status is essential for efficient irrigation practices.

For years, superintendents have used many means to guide turfgrass irrigation. Some methods are more qualitative and adapted to quick field adjustments, while others are more time consuming but provide quantitative information. Water conservation and turfgrass quality issues will dictate that the positive attributes of all these methods be accentuated.

Watering by feel

The most commonly used method of assessing moisture status is through experience with visual determinations. Early detection of moisture stress is the observation of "wilt," a physiological condition that occurs when the cells within the turfgrass plant lose turgor pressure.

In addition to color change, other characteristics of "wilt" include narrowing of the leaf blade and an increase in the turfgrass canopy temperature compared to hydrated turf.

One of the earliest physical characteristics of turfgrass "wilt" is a change in color. As moisture becomes limiting, plants will change from a healthy green to a bluish hue and eventually a purplish black color. In the case of severe moisture stress, the turf will take on a brown straw color. If detected early and sufficient irrigation is applied, many turfgrass species will regain turgor pressure and the green color will return within a few days.

However, in the case of prolonged drought, turfgrass may either enter into an induced dormancy (at which time growth will continue only when water is no longer limited) or the turf may die.

Other characteristics of "wilt' include narrowing of the leaf blade and an increase in the turfgrass canopy temperature compared to hydrated turf. At the onset of moisture stress, a temperature increase can be detected by placing a hand on green turf and the other hand on stressed turf, much as a parent would check a child for fever. While visual and sensual assessments are quick and relatively easy, they are purely qualitative.

Measuring water

A physical measurement of water is a quantitative assessment of the moisture status or level within the turfgrass rootzone. When this is made on a weight basis it is called the gravimetric water content (indicated as qwt). This technique requires the extraction of a plug of soil, weighing the moist plug (wet weight in grams), drying it in an oven at 105° C overnight, and re-weighing the dried plug (dry weight in grams). qwt (in g g-1) can then be calculated (Equation 1).

Equation 1

$$\grave{e}_{wt} = \frac{\text{[Wet Weight (g)]-[Dry Weight (g)]}}{\text{[Dry Weight(g)]}}$$

Other information can be determined from the removal and drying of a plug. Density is the mass of an object that occupies a given volume. In soils, bulk density (BD) is the mass (g) of dry soil, including pore space, contained in a given volume (cm-3) and is often used as a measure of soil compaction (Equation 2). As the mass of dry soil increases in a given volume, so does BD, which indicates increased soil compaction. Particle density is the density of an individual soil particle or solids and is commonly approximated at 2.65 g cm-3.

Equation 2

$$\text{Bulk Density} = \frac{[\text{Dry Weight of soil (g)}]}{[\text{Volume of soil (cm}^3\text{)}]}$$

Volumetric water content (qv) is the volume of water within a volume of soil and can be calculated (Equation 3). As roots explore a volume of soil for water, the moisture environment within the rootzone is more realistically described by qv than qwt. Also, qv values can be converted to equivalent water depths, much like measurements made with a rain gauge (Equation 4). For example, a 30-cm layer of soil with a qv of 0.20 cm3 cm-3 would contain 6 cm of water.

Equation 3

$$è_v = (è_{wt}) \leftrightarrow (BD)$$

Equation 4

$$\text{Depth of water} = (è_v) \leftrightarrow (\text{depth of soil})$$

Important for turfgrass growth and development, air and water are held within the pore spaces between soil solids. Total porosity (et) is the measure of voids relative to the total volume of bulk soil and is calculated by Equation 5. Bulk density is inversely related to et, as bulk density increases the porosity decreases. United States Golf Association (USGA) specifications for root zone putting green media recommend a et of 0.35 –0.55 cm3 cm-3 (The USGA Green Section Staff, 1993).

Equation 5

$$å_t = 1 - \frac{\text{—Bulk Density}}{\text{Particle Density}}$$

While pulling a plug provides significant data, it is a destructive method requiring time to complete.

Environmental guided irrigation

Another method used to guide turfgrass irrigation is based on estimated daily turfgrass evapotranspiration (ET) rates. Evapotranspiration is the combined loss of water through plant transpiration and evaporation of water from the soil.

The concept of this technique is to use local weather information (i.e. temperature, relative humidity, wind velocities, solar radiation, etc.) in an equation, or model, which estimates the amount of moisture lost through ET. Enough irrigation is then applied to compensate for the moisture lost.

There are several models that estimate ET and are used to guide turfgrass irrigation. Fry et al. (1997) found turfgrass species, mowing height and nitrogen fertility can influence the accuracy of ET models. Also, certain models may provide more accurate estimates in one part of the country compared to another. Using ET to guide irrigation requires the input of many factors and site specific calibration.

When the proper information is used, ET can be an effective method of managing water resources, however knowledge of many variables is required for efficient use.

Probe guided irrigation

Researchers have continually shown that efficient water management is achieved by using a reliable device to guide irrigation timing. The use of instrumentation, or sensors, is yet another method of determining soil moisture status.

There are various types of instruments that measure moisture content (i.e. porous blocks, thermal dissipation blocks, tensiometers, neutron probes, dielectric constant probes, and others), with each having positive and negative attributes. Permanently buried sensors have the potential to be valuable tools in the decision process of when to irrigate and how much water to apply. Criteria for an effective moisture probe for golf course use include readings that are:

- accurate;
- independent of soil type or organic matter content, and soil compaction;
- independent of pesticide or fertilizer application (soil ionic strength);
- in a real-time manner;

• easily interfaced with a computer system;
• the probe should be relatively permanent; and
• small enough not to disturb the playing surface or required maintenance practices (i.e. pin locations and routine aerification).

Tensiometers

When compared to a set irrigation schedule, Morgan and Marsh (1965) reported on a clay loam soil, irrigation guided by tensiometers installed at two depths (5 cm and 12.5 cm) could reduce water use by 83%. On 'Tifgreen' bermudagrass (Cynodon dactylon X C. transvaalensis) managed as golf course fairways, Augustin and Snyder (1984) were able to use 42% to 95% less water using tensiometer-guided irrigations compared to plots that received daily irrigation.

Improved root vigor and depth were also observed on tensiometer irrigation guided greens, while playability did not suffer. Morgan et al. (1966) reported less compaction under tensiometer-guided irrigation compared to set irrigation schedules on a sandy loam soil with and without amendments. Also, appropriate irrigation practices can influence nutrient leaching. In a sandy soil, Snyder et al. (1984) observed a reduction in nitrogen leaching under tensiometer-guided irrigations.

Reduced water use, improved root vigor and depth were observed on tensiometer irrigation guided greens, while playability did not suffer.

It has been shown that irrigations guided by tensiometers can reduce irrigation frequencies, soil compaction and nutrient leaching. However, water savings have not been demonstrated on a modified sand profile construction as prescribed by the United States Golf Association (USGA). Also, tensiometers require continual maintenance, calibration, and do not fit well into an automated system.

Neutron probe

For research purposes, Aragao et al. (1997) found in situ neutron probes beneficial for scheduling irrigation on sand based putting greens. Because neutron probes use radioactive materials (radium-beryllium or americium-beryllium) to measure hydrogen ions associated with water molecules they are highly accurate (Miller and Gardiner, 1998; Evett and Steiner, 1995).

However, due to the use of radioactive materials, special licensing is required and therefore neutron probes can not be permanently imbedded in the soil (Devitt and Morris, 1997; Miller and Gardiner, 1998; Evett and Steiner, 1995).

Because neutron probes use radioactive materials to measure hydrogen ions associated with water molecules, they are highly accurate.

Neutron probes are unreliable near the soil surface (Hanks and Ashcroft, 1980; Kome, 1996; Song et al., 1998). Although highly accurate at measuring soil water content, neutron probes are not practical for golf course use due to limitations and the high cost associated with the system.

Dielectric probes

A relatively new technology to measure soil moisture is the measurement of the soil dielectric constant (DC). The DC is a unitless measurement of a solvent's ability to keep opposite charged particles apart, in this case the solvent is water (Voet and Voet, 1995). The DC of dry soil ranges from 2 to 5, while the accepted DC value for water is 78 (Rial, 1999; Miller and Gardner, 1998; da Silva et al., 1998). Due to the difference between dry soil and water, moisture content can be measured. Greater moisture contents cause higher DC values while lower DC readings indicate reduced moisture content.

There are two basic types of probes that measure DC — time domain reflectometry (TDR) probes and capacitance probes.

Time domain reflectometry is a safe technique that provides reliable, instantaneous readings that can be automated. It operates by emitting an electromagnetic pulse from a source through a wire and into two parallel probes in the soil. An oscilloscope, is used to measure the return speed of the pulse to the source. The time for the pulse to travel down the wire, through the probes, and return to the source is a function of the DC. When the soil matrix contains moisture, the return time is slowed due to the high DC of water (Devitt and Morris, 1997; Miller and Gardner, 1998).

When compared to moisture contents from neutron probes and gravimetric techniques, Hanson and Peters (1997) found good correlation with several commercially available TDR probes. In a sandy soil, Cereti et al. (1997) observed good relationship between gravimetric and TDR techniques.

In a study conducted on a golf course fairway, Kome (1996) found TDR probes to be useful in turf irrigation scheduling. When compared to weighing lysimeters in a turfgrass ecosystem, Young et al. (1997) found TDR probes measured up to 96% of the water lost through ET. However, TDR instrumentation is expensive and due to the length of the probe (30 cm or greater), it is not readily applicable for golf course use.

Like TDR, capacitance probes (CP) measure water content based on soil DC. Capacitance probes can be buried in the soil, are small (about twice the size of a golf ball), easily integrated into automated data collection systems, and are less expensive than TDR (Devitt and Morris, 1997). As a result, CP can provide real time moisture information such that turfgrass managers can quickly and accurately assess moisture in individual greens. Also like TDR, soil temperature and ionic strength can influence readings (Campbell, 1990). However, some CPs measure soil salinity and temperature along with DC, allowing for more reliable moisture readings.

Although only limited data exist for the use of CP in turfgrass, Starr and Paltineanu (1998) found CP to provide acceptable real-time sensitivity when measuring soil water moisture in field-grown corn. With further research and advancements in technology, CP may prove to be an economically justifiable tool for guiding irrigation practices on golf courses.

Other probes

Other types of probes have been used to determine soil water content. On a USGA specification rootzone media, Freeland et al. (1990) used parallel, bare wire ends to measure soil resistivity. An empirical equation was used to convert resistivity values to moisture contents. While this technique is inexpensive, rapid and useful in measuring relative moisture contents, sensors are sensitive to fluctuating soil temperatures, compaction and soil ionic concentrations.

Song et al. (1998) used a dual probe heat-pulse technique to measure soil moisture in laboratory packed columns seeded with "Kentucky 31" tall fescue (Festuca arundinacea Schreb.). The dual-probe heat-pulse technique is nondestructive, easily automated and not sensitive to soil bulk density. However, the accuracy is subject to soil temperatures and low water contents, although the authors did not feel that these limitations were of practical significance.

While this technique is inexpensive, rapid and useful in measuring relative moisture contents, sensors are sensitive to fluctuating soil temperatures, compaction and soil ionic concentrations.

Another type of probe used to measure soil moisture is thermocouple psychrometers. This technique is based on measuring the relative humidity of a sample and relating it to water potential. Unfortunately, due to temperature differentials when buried in the upper 30 cm of soil, the reliability of thermocouple psychrometers were compromised (Brown and Oosterhuis, 1992). Although very sensitive, this technique is not practical for golf course use because a calibration curve is required and the lack of reliability in shallow soils.

Conclusions

Although personal sensory methods for assessing water for turfgrass will always be used, instrumentation will become a more important part of irrigation scheduling to accurately justify the expense of irrigations.

As technology improves and water restrictions are levied, golf course superintendents will have to justify water usage and a tool that not only provides reliable soil moisture status but also allows the manager to log daily water status will be a benefit. Of the probes discussed, capacitance probes may offer an affordable option to guide water usage with a high degree of accuracy and because of their small size, do not interfere with standard cultural practices.

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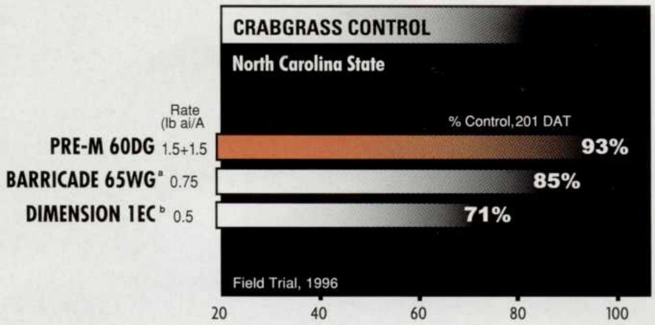

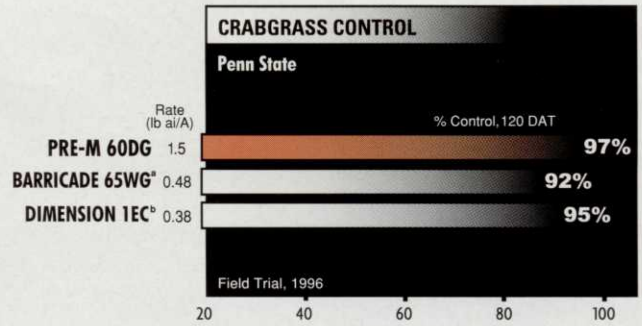

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TEAM[c]	H	M	M	M	M	M	NR	NR
RONSTAR[d]	M	H	NR	M	M	NR	NR	NR
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*Source: Kline & Company Report, US Acre Treatments by Turf Management.

Management of Saline Irrigation Water

Dr. Ken Marcum

Salinity problems associated with poor quality irrigation water are becoming more prevalent, not only in western states, but across the country as fresh water sources become more scarce. Secondary water sources, such as effluent, are increasingly being used for turfgrass irrigation due to increased urban demand for potable water. Some western states, including Arizona, require the use of effluent for turfgrass irrigation when available.

Salt problems can originate from salty soils, typically found in western states where evaporation exceeds rainfall. But often, good soils become salty, or loose their structure and drainage, by irrigating with low quality water and using incorrect irrigation practices. Managing effluent or other saline irrigation water sources can be a complicated process affected by a number of factors, including the total salinity of the irrigation water, type of saline ions present in the water and soil, soil texture, and turfgrass species and cultivar used (I'll cover the turfgrass factor in a subsequent article).

Water salinity level

Total salinity of water is measured by the electrical conductivity (ECw). You might find total salinity expressed as: decisiemans per meter (dS/m), millimhos per centimeter (mmhos/cm), or micromhos per centimeter (µmhos/cm). The first two units (dS/m and mmhos/cm) are identical: dS/m is the contemporary usage. Micromhos/cm (µmhos/cm) is 1000 times smaller than dS/m.

The other method of reporting salinity is on a concentration basis, in parts per million (ppm) or total dissolved solids (TDSmg/L). These two units are the same: 1 mg of saline ion per liter water is actually 1 part per million. However, water testing labs don't actually measure the concentrations of saline ions to come up with values for ppm or TDS - it's too expensive. Instead, water salinity is measured by conductance (dS/m), and converted to ppm by using a correction factor, typically 640. The problem is that this conversion factor can vary widely (from 400 to 1,000), depending on the various types of ions present in the water. Therefore, dS/m is more exact, while ppm and TDS values are estimates.

Summary of Salinity Units

dS/m = mmhos/cm

µmhos/cm X 1000 = dS/m

and:

ppm = TDSmg/L

ppm X 640 ª dS/m

≠ (approximately!)

The U.S. Salinity Laboratory has classified the salinity hazard of irrigation waters in the table below.

Salinity Level

Units	No Problem	Moderate	Severe Problem
dS/m	<0.75	0.75 -3.0	>3.0
ppm	<480	480 - 1920	>1920

Waters having ECw less than 0.75 dS/m are considered good quality, from 0.75 to 3.0 medium quality, and waters with ECw greater than 3.0 are low quality, and usually not recommended for irrigation without careful management.

Leaching soils

Leaching of salts out of the root zone is critical when using low quality water sources for irrigation. Plants transpire pure water, leaving behind the salts, which accumulate in the soil profile. That's why a soil can gradually become much more saline than the water used to irrigate it. The soil must have adequate permeability to allow for deep leaching (at least 5-6 feet). If water doesn't drain below this depth, subsurface drainage tiles may be necessary to prevent the development of a high water table, which can salinize a soil by capillary rise of drainage water to the soil surface.

The "Leaching Requirement" of a soil is

the excess amount of irrigation water, above what the turfgrass uses as ET (evapotranspiration) that must be applied to flush out excess salinity. The idea is to maintain the soil salinity at a fairly constant, acceptable salinity level. The leaching fraction is the minimum amount of water needed to maintain the soil at a given salinity level. Therefore, it's not a single leaching event, but a continuing process.

If water doesn't drain below 5 to 6 feet, subsurface drainage tiles may be necessary to prevent the development of a high water table, which can salinize a soil.

The following formula is used to calculate leaching fraction:

LF (Leaching Fraction) = ECiw ECdw

where ECiw is the EC of the irrigation water, and ECdw is the EC of the drainage water (equal to the EC, or salinity level, which your turfgrass can tolerate).

Here's an example. If you are irrigating an overseeded perennial ryegrass fairway which can tolerate a soil salinity of 4-8 with effluent water having an ECiw of 2, then ECiw = 2, and ECdw = 4-8 (let's use 6), then:

LF = 2/6 = 33%

Your leaching requirement is 33%, meaning that you need to apply 33% more water than what the turf uses [ET + (ET X .33)] in order to maintain the soil salinity at an acceptable level (in this case 6 dS/m).

Maintaining proper ion balance

As long as you can maintain a soil permeability adequate to meet your leaching requirements, you can use fairly salty water to irrigate turfgrass. For example, bermudagrass can tolerate soil salinity of 10 to 16. The problem is that soil structure can be broken down, with subsequent loss of permeability when using salty irrigation water, due to the effects of sodium or carbonates.

When permeability is lost, meeting your prescribed leaching fraction becomes more difficult. Slower drainage results in wet soils, which are susceptible to compaction, and even further reductions in soil permeability - a vicious cycle results. Finally, salt builds up to the point where the turf is damaged or lost.

Why does this happen? The sodium (Na^+) ion, a primary component of most saline water, destroys soil structure by dispersing clay and silt particles, which are normally bound together as soil aggregates. However, calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, due to their high charge densities, counteract the dispersive effects of Na^+ on soil particles, thereby maintaining soil structure. The most important factor for maintaining soil structure and good drainage is not just the Na^+ content of the water, but the balance of Ca^{2+} and Mg^{2+} relative to Na^+.

As long as you can maintain a soil permeability adequate to meet your leaching requirements, you can use fairly salty water to irrigate turfgrass.

The ratio of these three ions, which determines the permeability hazard of irrigation water, is expressed as the sodium adsorption ratio (SAR):

SAR = Na _ Ca+Mg/2

In this ratio, ion concentrations are in miliequivalents per liter (meq/L). To convert ppm (often given in soil/water reports) to meq/L, use this formula:

meq/L = ppm ∏ equivalent weight
Equivalent weights are:
Na^+ = 23
Ca^{2+} = 20
Mg^{2+} = 12.2

According to the U.S. Salinity Laboratory, irrigation water having SAR values greater than 9 may cause permeability problems in finer textured soils. However, coarse soils can tolerate higher levels. Sands, including USGA specification greens, can usually tolerate water with a SAR up to 15 with few problems. Waters with SAR's above 15 are generally not suitable for irrigation without prior treatment.

Sodium is a major component of saline irrigation waters, and therefore many such waters have unfavorable SAR's. To combat this, various soil and water amendments can be used. Gypsum ($CaSO_4$), a Ca^{2+} salt, is incorporated into soils adversely affected by Na^+ (sodic soils). Gypsum reacts with Na^+ to form $NaSO_4$, which is then readily leached out of the soil profile. The free Ca^{2+} can then bind to soil particles, thereby improving soil structure. The reaction of gypsum is:

2 Na—soil + $CaSO_4$ Æ Ca—soil + Na_2SO_4

However, because of gypsum's low solubility, it is usually incorporated into the soil, or in the case of turfgrass, spread over the turf. It is best to do this during a cultivation operation to facilitate incorporation into the soil. The gypsum requirement (GR), in tons per acre, needed to remove soil Na^+ is calculated by: $GR = 1.72 \times Na^+$, where Na^+ is in meq per 100 grams of soil (given in soil analysis reports). For example, if the soil exchangeable Na^+ is measured to be 8 meq/100 g, you would need $8 \times 1.72 = 13.7$, or 7 tons of gypsum per acre to totally neutralize the exchangeable soil Na^+. Gypsum should be applied at approximately 1 ton/acre (ª50 lbs./1000 ft^2), with 2 or 3 applications possible per year.

Sulfur (S) can also be used to remove soil Na^+. First, S reacts oxygen to form sulfuric acid, which then reacts with $CaCO_3$ (calcium carbonate) to form gypsum:

S + O_2 + H_2O Æ H_2SO_4
H_2SO_4 + $CaCO_3$ Æ $CaSO_4$ + CO_2 + H_2O

Gypsum then reacts with soil Na^+, removing it. Sulfur is about 5.6 times more efficient in removing Na^+. In the above example, you would only need $7/5.6 = 1.25$ tons per acre. However, sulfur is about twice as slow as gypsum. Also, you need an alkaline soil, with plenty of $CaCO_3$ present, typical for western soils. Finally, sulfur can burn turf. Sulfur should not be applied to turf above 5 lbs/1000 ft., unless the surface soil is high in free $CaCO_3$.

The acid injection option

Sulfur and gypsum are not soluble, so must be applied to the soil or turf. For this reason, many turf managers are using "acid injection", or injecting sulfuric acid into their irrigation water. The strategy here is to continually inject sulfuric acid into the irrigation water to provide the soil with enough S to prevent a Na buildup in the soil. Sulfuric acid injection cannot rejuvenate a soil that is already sodic (Na^+ affected). Instead, it is a merely a preventive measure. Also note that sulfuric doesn't directly remove Na^+ from the water, it is just providing the soil with S, which binds and removes Na^+ in the soil. However, one added benefit of acid injection is to remove carbonates.

Carbonates (CO_3^-), which are present in some irrigation waters, can cause Na^+ problems indirectly, by precipitating soil Ca^{2+} and Mg^{2+} as limestone or dolomite, thereby shifting the balance in favor of Na^+:

CO_3^- (or HCO_3^-) + Ca^{2+} (or Mg^{2+}) Æ $CaCO_3$ (or $MgCO_3$)

Other management practices, such as encouraging good drainage by installation of subsurface tiles and by periodic core aerification, returning organic matter (in the form of clippings) to the soil, blending poor quality irrigation water with good quality water, and using salt tolerant turfgrasses are important. Managing saline water and soil is complex, and there are no "quick fix" miracle products available. Knowledge of the factors related to soil and water salinity, coupled with good management practices used on a continuing basis are essential for long-term success.

— Ken Marcum is assistant professor, turfgrass management, in the Department of Plant Sciences, at the University of Arizona.

Green Winter Color for Warm Season Lawns from Overseeding with Cool Season Species

By David E. Longer

Proven warm season grasses such as hybrid bermudagrass (Cynodon dactylon L.) and zoysia (Zoysia japonica Steud.) have become the preferred lawn species for manysouthern home owners because of their ability to withstand prolonged periods of heat and drought and increased wear. Improved zoysia cultivars have better disease resistance and improved shade tolerance than their predecessors.

Need for overseeding

Major drawbacks of zoysia and bermudagrass are that they must be established vegetatively, i.e., by laying sod, sprigging or plugging, and the aboveground leaf mass turns an aesthetically unpleasant straw color with onset of cold weather.

Considerable research has been done on fall overseeding of cool season species into established cool season turfs. Seeding tall fescue in the fall into an existing tall fescue lawn to enhance turf density in the fall and the following spring and summer seasons is a well known practice.

Less is known about overseeding cool season species into established warm season lawns. For this type of system to appeal to homeowners, it must be effective in establishing year-round green turf color, something that is fairly inexpensive and relatively simple to accomplish.

Overseeding with cool-season species

A series of experiments were initiated at the Main Agricultural Experiment Station (MAES) in Fayetteville, AR, in 1998 to determine if cool season turfgrass species could be overseeded into established warm season lawns and provide year long, green ground cover with very low labor and capital inputs.

The cool season grasses were blends of several species and were obtained from the former Loft's Seed Co. The blend known as Triplex consisted of equal portions of three perennial ryegrass (Lolium perrene L.) cultivars: 'Palmer III;' 'Prelude III;' and 'Repel III.'

For this type of system to appeal to homeowners, it must be effective in establishing year-round green turf color, something that is fairly inexpensive and relatively simple to accomplish.

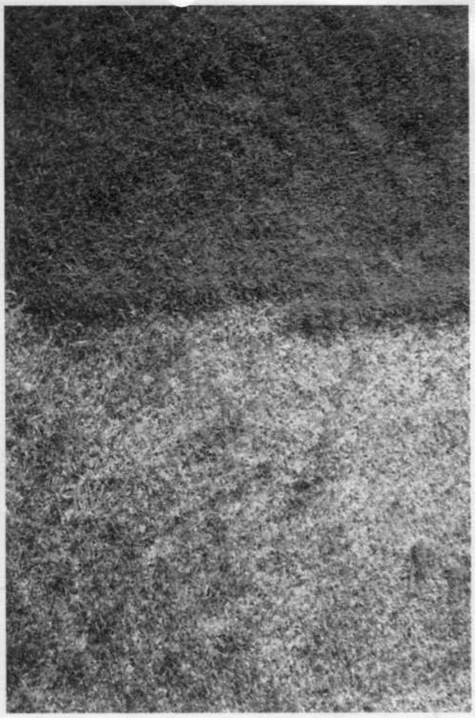
The other blend known as "Athletic Field Mix" consisted of 10% perennial ryegrass, Palmer III, 10% of Kentucky bluegrass (Poa pratensis L.), 'Preakness' and 80% tall fescue (Festuca arundinacea Schreb.) 'Rebel III.'

In addition to the two blends, other treatments included two planting dates: mid-September and mid-October; and scalping or not scalping the warm season species prior to overseeding. Seeding rate for each blend at each planting date was 5 lb./1000 sq. ft. and each plot was fertilized (19-19-19) at the rate of 1 lb./1000 sq. ft. two weeks after seedling establishment to promote good shoot and root growth throughout the fall.

All other management inputs, such as weed control, were targeted toward the period when the warm season species were actively growing. All test plots were evaluated monthly for color, quality, density and percent weediness

The field tests were established as a split, split-plot with blends being the main split

Analysis indicates that cool season turfgrass species may be able to provide aesthetically pleasing winter color when established in warm season lawns.



and planting date, and preplant scalping as subsequent splits.

Immediately following both seedings, plots were irrigated daily until emergence, which occurred in each plot within eight to 12 days. All plots were qualitatively rated each month, and mowed weekly to 0.75 in. during periods of active growth. Final assessments were based on monthly values of turf color, density, quality and weediness.

Results of the experiment

Zoysia and bermudagrass main plots were separate from each other and analyzed as separate experiments. The treatment plots were established within each main plot.

Zoysia plots showed no treatment differences for either planting date or overseeding species. All overseeding treatment combinations provided an improvement in winter turf color when compared to the control plots, which were not overseeded (Figure 1). Bermudagrass seemed to be more responsive to overseeding by cool season species.

TABLE 1. Density values for bermudagrass overseeded with cool season turf grass blends. Ratings for months of Dec., Mar., and May. Density ratings (†) (Rating scale 1-9, 9= best).

		Blends					
		Triplex			Athletic. Field Mix		
Planting Date	Preplant Scalping	Dec.	Mar.	May	Dec.	Mar.	May
Early	No	7.0 (†)	6.0	7.0	9.0	7.7	7.7
	Yes	8.3	7.3	7.7	9.0	7.3	7.7
	LSD (0.05)	1.2	1.2	n.s	n.s	n.s	n.s
Late	No	6.7	7.7	7.3	6.0	7.7	7.3
	Yes	6.3	7.0	6.7	6.7	7.7	7.3

† Denotes in columns not followed by same letters are significantly different (LSD p<0.05)

Turfgrass density was increased in the Triplex blend for the December and March evaluation periods in the early plantings that were scalped prior to overseeding. (Table 1.) The density values were generally higher in early plantings for both blends but not all dates were statistically significant.

Turfgrass color was greatly influenced by overseeding, as would logically be expected, since the bermudagrass had entered winter dormancy and achieved the characteristic straw color by the time the plots were evaluated.

The Athletic Field Mix blend, averaged for early and late seeding dates, was superior to Triplex in color evaluations

Both blends showed large differences in the December evaluations for turf color in the early seeded plots. Scalping treatments proved mostly ineffective.

Early seeding advantages had disappeared by the time the plots were evaluated in March and May when the later seeding dates had caught up (Table 2). The Athletic Field Mix blend, averaged for early and late seeding dates, was superior to Triplex in color evaluations in March and was still better in May, but not significantly better.

Since the control bermudagrass plots would have been rated zero because of dormancy, all overseeding treatments were an improvement over that. The weediness found in the bermudagrass study was due largely to the relatively low density of the established bermudagrass turf prior to overseeding. The early overseeded cool season species were able to establish and compete favorably with the winter weeds, but the late planted cool season species were not.

Percent weediness values were as much as 15% greater in the late planted treatments when compared with the early seeded plots in the March evaluation period. (Table 3).

Getting good color

Visual and qualitative analysis indicate that cool season turfgrass species may be able to provide aesthetically pleasing winter

TABLE 2. Color values for bermudagrass overseeded with cool season turf grass blends. Ratings given for December, March., and May. (Rating scale 1-9, 9= best).

		Blends					
		Triplex			Athletic. Field Mix		
Date	Scalped	Dec.	Mar.	May	Dec.	Mar.	May
Early	No	8.7 (†)	6.0	6.7	9.0a	7.0	7.3
	Yes	8.0a	7.0	7.0	8.0a	7.7	7.3
Late	No	6.3b	7.3	7.0	6.0b	7.5	7.3
	Yes	6.3b	7.3	6.7	6.3b	7.7	7.7
Mean		6.9 (‡)	n.s	n.s	7.5	n.s	n.s

† Denotes in columns not followed by same letters are significantly different (LSD $p<0.05$)

‡ March mean values compared in rows [SD - 0.33 ($p<0.05$)]

TABLE 3. Percent weediness values for bermudagrass overseeded with cool season turfgrass blends. Ratings given for Dec., Mar,. and May, 1998.

	% Weediness		
Date	December	March.	May
Early	1.5	0	0
Late	4.5	14.8	7.2
LSD ($p< 0.05$)	2.7	7.5	3.4

color when established in warm season lawns. All overseeded plots were no lower than 6 (9 is best) on the color scale and much better than the zoysia and bermudagrass control plots in terms of appearance.

Early planting (mid-September) provided superior density and color ratings in many cases when compared to the mid-October seedings. Bermudagrass, in general, seemed to be more responsive than zoysiagrass to overseeding of cool season species. Early seeded bermudagrass plots were nearly free of winter or cool season weeds, whereas the later overseeding did experience some cool season weed infestation.

Overseeding of warm season lawns with cool season blends consisting of perennial ryegrass, tall fescue and Kentucky bluegrass provided an inexpensive, low maintenance green lawn throughout the winter months in Northwest Arkansas. This process may be worthwhile for warm season lawns throughout the "transition zone."

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