A PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

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BACK TO BASICS

Water
How Turfgrasses Obtain and Use Moisture

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Having survived a 1998 summer season that offered some of you the driest weather on record, it might be useful to review some of the basic ideas on how and why turfgrasses uses water. Being familiar with these principles of water use may help you decide when water conservation is wise and when it may do more harm than good.

The management of water use on turf has been considered within these pages (Hull 1996a; Richie et al. 1997; Shank, 1998; Qian and Engelke 1999; Richie et al. 1999) and elsewhere (Hull 1996b; Fry et al. 1998; Fry and Jiang 1998). Most of these articles assume that the reader has a basic understanding of how turfgrasses acquire, transport and lose water. This is generally a safe assumption but might not always be true because of advances in our understanding of plant water relations. In this *Back to Basics* piece, I will review some long accepted concepts and add a few new wrinkles to our understanding of water use by turfgrasses.

How water functions in turf

Water is the medium of all biology. Life presumably originated in the primordial seas and to this day operates within an aqueous environment that resembles the probable composition of early oceans. Life is essentially a complex of controlled chemical reactions that function in water. Water is even a substrate for some of these reactions, e.g. photosynthesis and hydrolysis.

As plants invaded and colonized the land about 450 million years ago, they created ways for maintaining the integrity of their aqueous environment while growing and reproducing in a largely dry and often hostile world. Today, turfgrasses are frequently managed under similarly hostile conditions. To survive, plants needed to evolve ways for absorbing water from where it was available (usually the soil), transporting it to above-ground organs (stems and leaves), and controlling its loss so aerial organs would not desiccate and die. Also, this transport of water from roots to shoots soon became the principal route by which plants also transported all essential mineral nutrients from the soil to shoot organs.

As this system evolved, the evaporative loss of water from leaves and other shoot organs could not be entirely prevented and still allow for the necessary exchange of atmospheric gases. This was not all bad because the cooling effect of evaporation proved useful for stabilizing shoot temperatures within a range that was compatible with life chemistry. Thus,

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while plants were able to grow on land, they retained the need for a constant supply of water to support life, transport nutrients and prevent aerial organs from overheating. Even today, plants depend on water for the same functions.

Water uptake from the soil

Water enters a plant root in response to a negative gradient in water potential. In other words, when the activity of water in the soil is greater than it is within the root, water flows into the root. The activity or potential (Y) of water in any situation is governed by its concentration and the pressure imposed on it. This is often expressed by the equation:

$$Yw = Ys + Yp$$

Yw = the water potential in the soil or within a plant cell and consists of two components: Ys = solute potential and Yp = pressure potential. The term Ys refers to the amount of solute (salts, sugars, acids, etc.) dissolved in water. Such solutes dilute the water and thus compared to pure water it has a negative potential. More stuff dissolved in water makes its solute water potential (Ys) more negative. The pressure potential (Yp) indicates the actual pressure exerted on water in the system being considered.

In a soil, the pressure on the soil water is approximately atmospheric pressure, which by convention is set at zero. Within a root cell, the pressure is likely to be positive if the cell is turgid and the root is not wilted. At times when water is under tension, it is under negative pressure and Ys will have a minus value.

In accordance with the above conditions, water will enter root cells only when the water potential inside the root is less than the water potential of the soil solution. In other words, water will move from a high potential in the soil to a lower potential in the roots, consistent with the general laws of nature and energy. If the soil dries and its water potential decreases (becomes more negative), water will continue to enter plant roots only if the root's water potential is even lower (more negative). This can occur if root cells increase their solute content or their water comes under negative pressure (tension). Water tension in root cells will cause roots and shoots to wilt and can even cause cells to collapse.

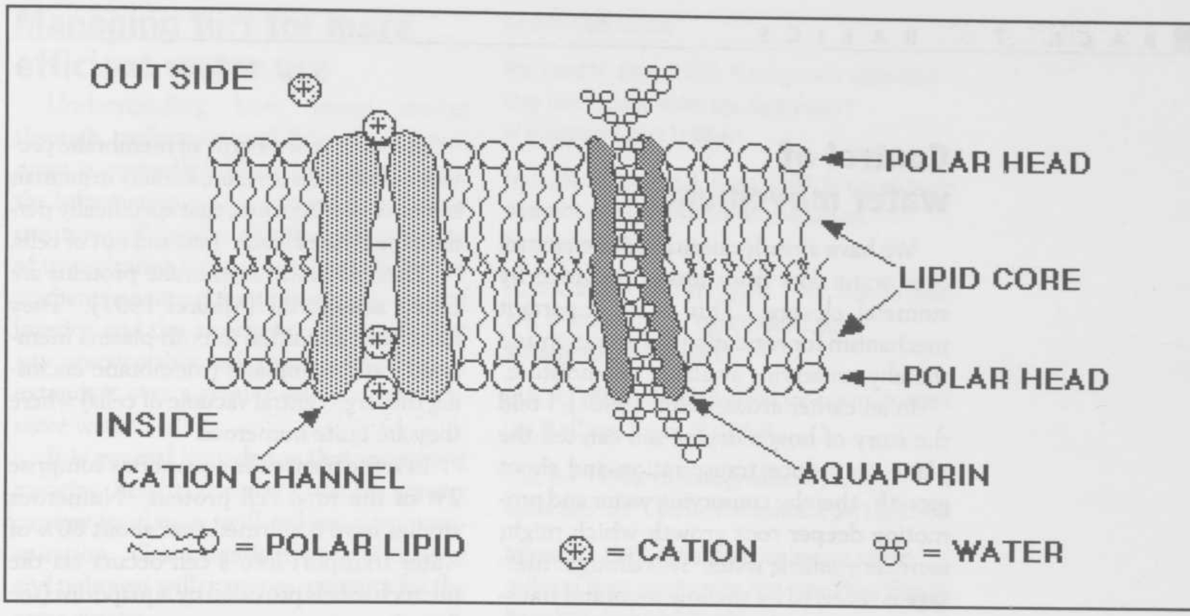
Transpiration — the force that keeps water flowing

The force that drives the flow of water from roots to shoots is generated by the evaporation of water from leaf surfaces (transpiration). Actually, it is not the leaf surface that loses water but the wet cell surfaces bordering the substomatal chambers within the leaves. These chambers are in contact with the atmosphere via small pores called stomata. Normally concentrated on the under surface of leaves, stomata provide openings to the leaf interior through which carbon dioxide can enter and oxygen can exit the leaf.

Stomata are open during the daylight hours while photosynthesis is occurring. They close during the night, virtually sealing off the leaf interior from the atmosphere and preventing most transpiration.

The force generated by water evaporating from leaves can be substantial. The magnitude of this force depends on the difference between water potential (Yw) within the substomatal chambers in the leaves and that of the atmosphere. Even under dry conditions, the substomatal chambers have a high relative humidity (~99 percent). This translates into an atmospheric water potential of -1.35 megapascals (MPa). A pascal is a very small unit of pressure but a million pascals (MPa) is equivalent to 145 pounds per square inch (psi).

If the atmospheric relative humidity is 50 percent, which is not unreasonable for a summer day, the atmospheric water potential would be -93.6 MPa (see figure). Under these conditions, the water potential gradient between the inside and outside of a leaf would be -93.6 -(-1.35) = -92.2 MPa, which is equivalent to a pressure of 13,376 psi. That constitutes the force driving water



Portion of a cell membrane showing polar lipids and two membrane spanning intrinsic proteins, an aquporin and a cation channel.

vapor out of a leaf through the stomata into the atmosphere. It also represents the force that lifts water from the soil to the tops of tall trees or into the leaves of turfgrasses. With forces of this magnitude, is it any wonder that turfgrasses lose water rapidly and will dry out the soil within a few days?

Water transport to leaves

The roots, where water is available, and the leaves, where water is lost, are connected by specialized cells called vessel elements. When mature, these cells are dead, lose their end walls and are lined up end-to-end forming long tubes. These tubes, called vessels, are ideal for transporting large amounts of water with relatively little resistance.

Vessels resemble corrugated pipes that are imbedded within the vascular bundles of leaf blades, leaf sheaths and stems and are continuous with similar vessel elements in the core of roots.

The negative water potential (suction) generated by transpiration from the leaves is transmitted through the vessels to the roots, where it causes water to flow toward the leaves replacing that lost through transpiration. This lowers the water potential of the roots and water flows into the roots from the soil.

As a result of the efficient transport of water through vessels from roots to leaves, the actual water potential gradient within the grass plant between roots and leaves is rarely more than one megapascal. As long as water is available in the soil, grass plants should experience little moisture stress even in the face of enormous forces driving water out of the leaves. When the soil begins to dry or roots are damaged by insects or disease, the influx of water will be limited and water loss from the leaves may easily exceed water absorption by roots.

In recent years, a type of membrane protein has been discovered that specifically permits the flow of water into and out of cells. These intrinsic membrane proteins are called aquaporins.

When this occurs, the water potential in the leaves drops below that of the leaf cell solute potential (Ys), eliminating cell turgor pressure and the leaves will wilt. The guard cells that border the stomata also wilt (lose turgor) causing the stomatal apertures to narrow or close thereby reducing further water loss. If this reduced rate of transpirational water loss becomes less than the rate of water uptake by roots, plants will recover from wilting often with little damage having been done.

Control of water movement

We have already considered the control over water loss from leaves provided by stomatal closure. This is an important mechanism for regulating transpiration and thereby conserving available soil moisture.

In an earlier article (Hull 1996a), I told the story of how a drying soil can tell the plants to reduce transpiration and shoot growth, thereby conserving water and promoting deeper root growth which might increase available water. This drought message is received by shallow roots and translated into production of the hormone abscisic acid (ABA). This hormone is carried via the transpiration stream to the leaves, where it promotes stomatal closure and inhibits leaf growth.

Increasing mowing height creates greater canopy insulation and reduces evapotranspiration. Similarly, grass stands of greater density and tightness will conserve moisture.

Inhibited shoot growth makes more photosynthetic product available for transport to the roots, where those deeper roots that still have adequate water are enabled to increase their growth and explore additional water supplies. In this way, the plant is warned well before drought stress occurs that water shortage is imminent and conservation measures need to be taken.

For many years, physiologists assumed that water movement was passive, responding to gradients in water potential, and was largely uncontrolled except by stomatal closure. Water crossed the outer cell membranes (plasma membrane) by moving through integral proteins that spanned the largely lipid (fat) membrane (see figure). It was believed that water could move only slowly across the lipid core of biological membranes, so most water had to cross via intrinsic membrane spanning proteins that exerted little or no control over water passage. Thus, water movement into root cells was pretty much uncontrolled.

In recent years, a type of membrane protein has been discovered, initially in animals but now also in plants, that specifically permits the flow of water into and out of cells.

These intrinsic membrane proteins are called aquaporins (Maurel 1997). They have been identified in both plasma membranes and tonoplasts (membrane enclosing the large central vacuole of cells) where they are quite numerous.

In some plant cells, aquaporins comprise 2% of the total cell protein. Numerous studies have confirmed that about 80% of water transport into a cell occurs via the microchannels provided by aquaporins (see figure).

This is not universally true in that some cells permit only about 20% of their water influx through aquaporins; the remainder moving through other intrinsic membrane proteins or diffusion through the lipid core. However, such cells have a much greater resistance to water uptake than cells better endowed with aquaporins.

The discovery of aquaporins not only explained how water can enter cells rapidly, it also indicated that the process of water uptake is regulated to a greater extent than had generally been recognized. Because aquaporins are proteins, their synthesis is directly under genetic control, which in turn is influenced by environmental, developmental and positional factors.

Plants can alter their rate of water uptake by synthesizing more or fewer aquaporin molecules. It also appears that the activity of aquaporins can be controlled by environmental signals such as drought, temperature and oxygen availability.

Binding a phosphate ion to an aquaporin molecule has been shown to increase its capacity to transport water. This process of phosphorylation is known to regulate biochemical reactions and this finding suggests that water transport may be under similar levels of control.

In short, water entry into cells and transport throughout a plant is much more tightly regulated than was ever thought possible only a few years ago.

Managing turf for more efficient water use

Understanding how water moves through turfgrasses and how this movement is controlled gives the turf manager the information necessary to manage water use more efficiently. Knowing that the rate of transpiration is influenced mostly by the gradient in water potential between the leaf interior and the atmosphere suggests that any practice that reduces this gradient or extends it over a greater distance will conserve water.

It is general knowledge that increasing mowing height, thereby creating greater canopy insulation, will reduce evapotranspiration. Grass stands of greater density and tightness will conserve moisture for the same reason.

Allowing turf to sustain mild drought stress before irrigating will induce physiological water conservation by the grass plants and promote deeper rooting. This both reduces water usage and makes the turf better able to exploit soil water resources. Less frequent but deeper irrigation is generally acknowledged to be more water efficient and promotes a tougher turf.

The recognition of aquaporin mediated water transport is too recent to have influenced water management strategies. However, it is reasonable to expect that turfgrass breeders will be able to use this information to create grass cultivars that are better able to absorb water and respond favorably to changes in water availability.

Understanding what environmental signals will enhance water movement also can be exploited by turf managers to increase water use efficiency or increase drought tolerance. Within a short time, this knowledge will likely be translated into improved turf management practices for greater water economy.

Dr. Richard J. Hull is professor of plant science and chairman of the Plant Sciences Department at the University of Rhode Island. His research has concentrated on nutrient use efficiency and photosynthate partitioning in turfgrasses and woody ornamental plants.

LITERATURE CITED:

Fry, J and H. Jiang. 1998. Plant growth regulators may help reduce water use. Golf Course Management 66(11):58-61

Fry, J.; N. Tissart and H. Jiang. 1998. Irrigation management and turfgrass pests. Golf Course Management 66(6):56-60.

Harivandi, M.A. and J.B. Beard. 1998. How to interpret a water test report. Golf Course Management 66(6):49-55.

Hull, R.J. 1996a. Managing turf for minimum water use. TurfGrass Trends 5(10):1-9

Hull, R.J. 1996b. Physiology affecting turfgrass water use. Golf Course Management 64(12):63-66.

Maurel, C. 1997. Aquaporins and water permeability of plant membranes. Ann. Rev. Plant Physiol. Plant Mol. Biol. 48:399-429.

Qian, Y.L. and M.C. Engelke. 1999. Turfgrass selection: Comparing three turfgrasses for minimum irrigation requirements, drought resistance and long-term performance. TurfGrass Trends 8(1):4-8.

Richie, W.E.; R.L. Green and V.A. Gibeault. 1997. Maximizing turfgrass irrigation efficiency. TurfGrass Trends. 6(3):1-9.

Richie, W.E.; R.L. Green and V.A. Gibeault. 1999. Using Eto to improve irrigation efficiency. TurfGrass Trends 8(4):11-15.

Shank, B.F. 1998. Taking responsibility for golf course irrigation systems. TurfGrass Trends 7(12):12-13.

Humic Substances
Their Influence on Creeping Bentgrass Growth and Stress Tolerance

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In the June issue, we summarized the nature and properties of humic substances and the possible ways that they influence plant growth. In this article, we present our research results dealing specifically with the effects of humic substances on creeping bentgrass (*Agrostis stolonifera* L.) growth and stress tolerance.

Although there has been substantial research concerning the effects of humic substances on field crops, information regarding application of humic substances to turfgrass has been limited. In 1975, Dormaar reported an increase in N uptake by rough fescue (*Festuca scabrella* Torr.) in response to application of some humic substances extracted from three soils while P, K, Ca, Mg, and Na uptake were unaffected.

Manufacturers claim massive root systems, better establishment, improved vigor, better tolerance to salt, heat and stress, increased nutrient uptake, improved soil structure, and greater fertilizer and pesticide effectiveness.

Varshovi (1991) studied the influence of a humate on growth and N uptake of bermudagrass (*Cynodon dactylon* Pers.), and concluded that application of humate alone did not increase N uptake and growth. He speculated that applying humates to established turfgrass with already sufficient organic matter in the rootzone could yield no extended response.

Dorer and Peacock (1997) evaluated liquid and granular humate applications to a creeping bentgrass putting green and reported no increase in leaf tissue concentration of N, P or K. Meanwhile, many commercial humates and humic acid (HA) products are being promoted for use on turfgrasses, especially on creeping bentgrass.

Creeping bentgrass is the grass of choice for putting greens in the northern United States and in the transition zone due to its superior quality. However, bentgrass is often difficult to manage during summer, when heat stress often results in a shallow root system and less healthy bentgrass is more prone to disease and insect damage.

Manufacturers of commercial humic products often claim benefits to turfgrasses, including: a more massive and deeper root system; increased grass establishment; improved plant vigor and survivability; improved salt, heat and other stress tolerances; increased nutrient uptake; improved soil structure; and increased effectiveness of fertilizers and pesticides.

In an effort to better understand how humic substances might affect creeping bentgrass, studies were conducted over a three-year period at North Carolina State University. The purpose of our research was to investigate the effects of application of humic substances, including both humates and humic acids, on the growth and stress tolerance (heat and salinity) of creeping bentgrass.

Photosynthesis, chlorophyll concentration, rooting and nutrition

Greenhouse experiments were conducted using a solution-culture (hydroponic) system to evaluate the effect of a commercial HA on the photosynthesis, chlorophyll concentration, rooting and nutrient content of "Crenshaw" creeping bentgrass. Bentgrass plugs were grown hydroponically in one-quarter-strength Hoagland's nutrient solution, which contained HA at 0, 100, 200, or 400 ppm (parts per million). Hoagland's solution contained all of the mineral nutrients needed for plant growth. Growing plants in Hoagland's solution ensured that they have adequate nutrient during the study.

Measurements of photosynthesis, chlorophyll concentration and root dehydrogenase (DH) activity were made weekly for one month. Root DH activity reflects the vigor and health of the roots. The more active the dehydrogenase is in the root tissue, the more healthy are the roots. All clippings harvested after HA application were combined for nutrient analysis. At the end of the study, root length and dry mass were determined.

The results showed that the photosynthetic rate of plants growing in 100 or 200 ppm solutions of HA rarely differed from that of the control. However, the 400 ppm treatment significantly increased net photosynthesis by as much as 20% (Fig. 1). Chlorophyll content did not vary in response to HA application on any sampling dates. Thus, it appears that the increase in net photosynthesis following HA application was due to some process other than increased chlorophyll production.

Humic acid had no promotive effect on root length after the original roots were excised. However, 400 ppm significantly increased root dry mass on all sampling dates. Root DH activity of plants receiving HA at 400 ppm was significantly higher than that of nontreated plants, with the increases ranging from 35% to 108% (Fig. 2). Root DH activity was determined using the TTC (2, 3, 5 - triphenyl tetrazolium chloride) reduction method. The more active the dehydrogenase is in the root tissue, the more TTC is reduced. The large increases in TTC reduction due to HA treatment suggest that root respiration was increased substantially by humic substances.

Sladky (1959a, 1959b) also reported increased plant respiration in response to HA. There is a close connection in plants between the energy-releasing process of respiration and the energy-consuming process of growth. Thus, increases in root growth might be due to the stimulation of enzyme systems by increased respiration.

Although treatment with HA caused significant increase or decrease in concentrations of several nutrients, the changes were relatively small, and probably not of biological significance.

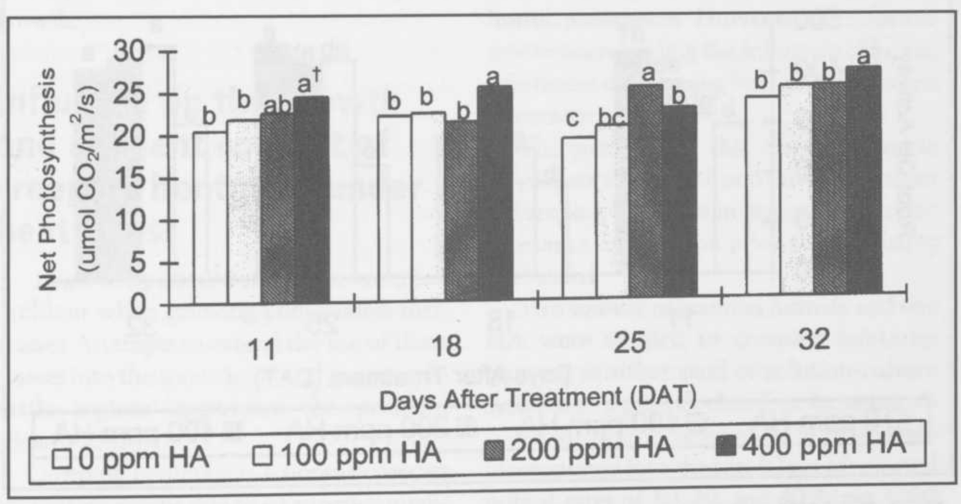

Fig. 1. Net Photosynthetic Rates of Creeping Bentgrass in Response to HA Application in One Greenhouse Solution-culture Experiment. + Means within the same DAT followed by the same letter are not significant at P=0.05 level.

Effects on root development, shoot growth, visual quality and nutrient concentration

The purpose of this experiment was to determine the potential of humic substances, including both humate and humic acid, to influence foliar growth, root growth and nutrient uptake of creeping bentgrass in sand-culture, solution-culture and under field conditions. In addition, the method of application (soil incorporated versus foliar application) was evaluated to determine if either method was preferable.

Creeping bentgrass rooting was increased by mixing granular humates into the top 10 cm of the rootzone or by surface application of humic acid to the rootzone prior to sod placement.

Greenhouse sand-culture, solution-culture experiments and one field experiment were conducted. Two commercially mined granular humates, a commercial HA and three IHSS (International Humic Substance Society) reference HAs extracted from leonardite, peat and soil were applied to creeping bentgrass growing in either sand, solution-culture or in the field. HA solution at different concentrations was either foliarly applied, or applied to the surface of the rootzone.

Creeping bentgrass rooting was increased by mixing granular humates into the top 10 cm of the rootzone (Table 1), or by surface application of humic acid to the rootzone prior to sod placement. This could have been due to more direct contact of humic substances with developing roots.

No single foliar-applied humic acid treatment consistently improved rooting compared to the control in either sand-culture or solution-culture experiments. Dorer and Peacock (1997) also reported no improvement in rooting for a "Cato"/ "Crenshaw" creeping bentgrass blend receiving foliar application of humates.

In general, application of humic substances did not affect clipping dry weight, and did not result in improved visual quality compared to untreated turf. These results corroborated those of Varshovi (1991) and Dorer and Peacock (1997). Nitrogen and calcium concentration of leaf tissue were relatively unaffected by the application of humic substances, regardless of application rate.

Phosphorous uptake in sand-culture was increased by incorporated granular

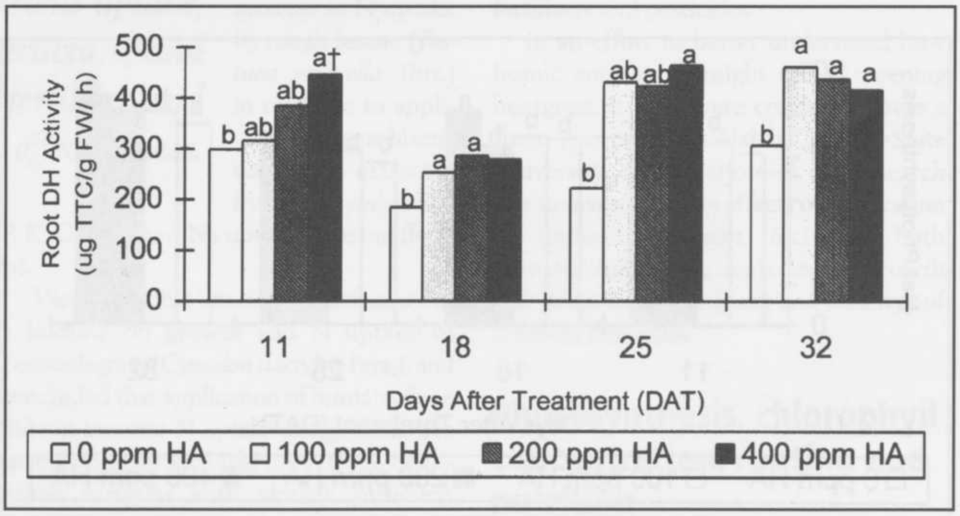

Fig. 2. Root DH activity of creeping bentgrass in response to HA application in greenhouse solution-culture. + Means within the same DAT followed by the same letter are not significant at P=0.05 level.

EFFECTS ON CREEPING BENTGRASS ROOT DEVELOPMENT

Table 1. Effects of humic substances on creeping bentgrass root development in sand-culture.

Humic Substance	*Formulation*	*Rootzone section (cm) 0-10*	*10-20*	*>20*	*Maximum Root Length*
		Root Dry Mass (g)			*— cm —*
Menefee Humate	G+	0.96 a +	0.36 a	0.17 a	36.9 a
Soil HA	S	0.81 b	0.32 ab	0.15 a	33.0 ab
Peat HA	S	0.79 bc	0.28 b	0.11 ab	33.8 ab
Leonardite HA	S	0.79 bc	0.31 ab	0.15 a	36.1 ab
Sustane HA	S	0.80 bc	0.28 b	0.09 ab	34.1 ab
Control	—	0.66 c	0.26 b	0.04 b	32.2 b

+ Mean separation within columns by Waller-Duncan K ratio (K=100) t-test. Means within columns followed by the same letter are not significantly different at P=0.05 level. + (G) Granular formulation incorporated into the top 10 cm of sand. (S) soluble formulation applied as a foliar spray.

humates, as well as by several of the foliarly-applied humic substances. Iron uptake was increased in the field, but not in sand or solution-culture experiments.

The influence of HA application on the nutrition of solution-grown plants was minimal. The lack of improved rooting was related in part to a lack of P uptake response in solution-culture and field-culture experiments. The leaf tissue concentration of several other nutrients were significantly affected by treatment application; however, the differences were so small that they were probably not important to plant growth.

Influence on the growth and nutrient content of creeping bentgrass under heat stress

High temperature stress is a common problem when growing cool-season turfgrasses. Attempts to extend the use of these grasses into the transitional and warmer climatic regions aggravates the problem (Beard, 1995).

Creeping bentgrass is a popular species for putting greens due to its superior quality; however, creeping bentgrass often declines during the summer months (Krans and Johnson, 1974, Carrow 1996), as it is extended beyond its normal regions of heat stress adaptation (Beard, 1995).

Improvement of heat tolerance in creeping bentgrass would enhance turfgrass quality and its use in warmer environments. Many efforts have been made to improve bentgrass heat tolerance (Beard 1995, 1997) including: modifying rootzone composition, using heat resistant cultivars, syringing and increasing air movement.

Manufacturers of humates and HA for commercial use often claim that plant heat tolerance might be improved by use of humic substances. However, no information exists regarding the influence of humic substances on creeping bentgrass heat stress tolerance.

The purpose of this research was to investigate the growth and nutrient content of creeping bentgrass in response to humic substance application prior to and during heat stress.

Two sources of granular humate and one HA were applied to creeping bentgrass growing in either sand or solution-culture systems in a growth chamber. In sand-culture, two sources of granular humate were incorporated into the top 10 cm of selected pots at rates of 10, 20, and 40 lb per 1000 sq. ft. The turf was grown for 31 days before heat stress was initiated.

In the solution-culture experiment, HA was added to nutrient solution at rates of 0, 100, 200, or 400 ppm immediately after heat stress was initiated.

In both sand and solution-culture experiments, creeping bentgrass was exposed to day/night (14h/10h) temperature regimes of 77/59, 95/77, and 104/86 F, for 38 days. Increasing day/night temperatures significantly reduced clipping dry weight, clipping water content, maximum root length and root dry weight in both experiments. Increasing day/night temperatures significantly decreased photosynthetic rates throughout the experiment. Humate application in the sand-culture experiment did not influence clipping dry weight, maximum root length, or root dry weight, and had minimal influence on water content. In solution-culture, HA application actually decreased clipping dry weight and water content in some measurements, but generally did not effect chlorophyll content or photosynthesis.

During salinity stress, HA application inconsistently influenced clipping dry weight and did not affect tissue water content, net photosynthesis or root growth.

Rooting was generally not improved by HA application during heat stress. Heat stress resulted in increased N content, decreased Ca, Mg, S, and B content, and had no influence on P and K content in sand-culture. Nitrogen, P, Mg, and S content increased, K and B content decreased, and Ca content was unaffected in the solution-culture experiment.

Increased level of nutrient uptake in solution-culture may have been due to less severe heat stress in the rootzone compared to sand grown plants. Application of humate did not influence the uptake of mineral nutrients in sand-culture. However, in solution-culture, HA application significantly reduced uptake of N, P and Mg, and increased uptake of K and B. Application of humic substances did not result in significantly improved heat tolerance.

Influence on the growth and nutrient content of creeping bentgrass under salt stress

Creeping bentgrass has been characterized as having very good salinity tolerance among the cool-season turfgrasses (Turgeon, 1996). Even so, increased salt tolerance in bentgrass is needed to minimize problems such as: increased salt accumulation in soil (Hoss, 1981), increased sea water encroachment into golf course irrigation sources and increased restrictions on use of potable water sources for irrigation (Marcum and Murdoch, 1990).

The adverse effects of salinity mainly involve two aspects: increased osmotic potential stress and possible toxic effects of excessive ions (Taiz and Zeiger, 1991). Humic acids have been reported in some studies to increase uptake of both macro and micronutrients (such as N, P, K, Fe and Zn), thereby improving the nutritional status of the plant (Gaur, 1964; Rauthan and Schnitzer, 1981).

Since humic substances have been shown to enhance photosynthesis, rooting and increase the uptake of Mg, S and P of creeping bentgrass (Liu, et al. 1998; Cooper, et al. 1998), one might reason that application of humic acid could improve plant response to salinity. Manufacturers of humates and HA often claim that plant salinity tolerance might be improved by use of humic substances. However, there are no scientific reports about humic acid application and its effects on plant salinity tolerance.

The purpose of this study was to evaluate the effects of humic acid application on creeping bentgrass salt tolerance by studying shoot growth, water uptake, photosynthesis, plant rooting and nutrient uptake following application of humic acid during salinity stress. "Crenshaw" creeping bentgrass plugs were grown hydroponically in one-quarter-strength Hoagland's nutrient solution containing HA at 0 or 400 ppm with salinity levels of 0.48, 8.00 and 16.00 ds/m (EC = electric conductivity). A salt mixture was formulated to mimic the average salt composition of sea water (Svedrup et al. 1959). Clipping dry weight, tissue water content, and net photosynthesis were measured weekly for one month. Maximum root length, and root dry weights from 0 to 10 cm and >10 cm rootzones were determined 31 days after treatment (DAT).

Turf was mowed three times weekly and clippings were dried and analyzed. Increasing salinity decreased clipping dry weight, tissue water content, net photosynthesis, and root length, but increased root dry weights. Salinity had less effect in reducing root growth than top growth.

During salinity stress, HA application inconsistently influenced clipping dry weight and did not affect tissue water content, net photosynthesis or root growth. Salinity decreased the uptake of N, P, K, Ca and S; increased the uptake of Mg, Mn, Mo, B, Cl and Na; and had no influence on the uptake of Fe, Cu and Zn. Application of 400 ppm humic acid during salinity stress neither increased the uptake of the nutrients inhibited by salinity nor decreased the elements which were excessive and toxic in the salinity solution. In general, application of HA did not improve salinity tolerance of creeping bentgrass.

Summary

Application of HA materials at 400 ppm in solution-culture significantly increased root mass, compared to untreated turf on almost every sampling date in greenhouse studies. The response to lower rates were not as conclusive. Although the materials improved the amount of roots present, they did not affect root length. When granular humates were incorporated into the rootzone to a depth of four inches, the rooting effects were stronger than the effect of foliar sprays.

Keep in mind that these results were from plants growing in sand or hydroponic solutions containing little or no native organic matter or humic substances. Rooting responses might be less evident on a putting green containing significant organic matter or naturally occuring humic substances.

Photosynthesis is an important process in a plant because it provides the plant with carbohydrates for growth and recovery from stress injury. Applying HAs at 400 ppm in solution-culture increased photosynthesis, compared to untreated turf on most dates when photosynthesis was measured.

The root DH activity was enhanced due to HA application, suggesting plant root respiration can be increased substantially by humic substances. In all the experiments evaluating nutrient uptake, the differences normally were very small — so small, in fact, that it is doubtful that these differences would result in turfgrass quality in the field. Application of humic substances did not improve heat or salt tolerance.

Although rooting, photosynthesis, root dehydrogenase, and nutrient content were often improved by humic substances; turfgrass shoot growth and visual quality rarely differed from untreated turf.

Although rooting, photosynthesis, root dehydrogenase activity and nutrient content were often improved by the application of humic substances; turfgrass shoot growth and visual quality rarely differed from untreated turf. Even so, we remain open minded regarding the potential benefits of making supplemental applications of humic substances. Applying the materials to low fertility soils or newly seeded greens might be useful in some putting green situations. Also, given the very low application rates required, one might consider their use to be cost effective for potentially improving rooting during summer months.

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REFERENCES

1. Beard, J.B. 1995. Turfgrass heat stress: what can be done ? Golf Course Management. 12: 52-55.

2. Beard, J.B. 1997. Dealing with heat stress on golf course turf. Golf Course Management. 7: 54-59.

3. Carrow, R. N. 1996. Summer decline of bentgrass greens. Golf Course Management. 6: 51-56.

4. Cooper, R.J., Chunhua Liu, and D.S. Fisher. 1998. Influence of humic substances on rooting and nutrient uptake of creeping bentgrass. Crop Sci. 38: 1639-1644.

5. Dormaar, J.F. 1975. Effects of humic substances from Chernozemic Ah horizons on utrient uptake by Phaselos vulgaris and Festuca scabrella. Can. J. Soil Sci. 55: 111-118.

6. Dorer, S.P., and C.H. Peacock. 1997. The effects of humate and organic fertilizer on establishment and nutrition of creeping bentgrass. J. Int. Turf Res. Soc. 55: 111-118.

7. Gaur, A.C. 1964. Influence of humic acid on growth and mineral nutrition in plants. Bull. Assoc. Fr. Itude Soc. 35: 207-219.

8. Hoss, D.D., 1981. Salt injury - an increasing problem. USGA Green Section Record. 19: 1-3.

9. Krans J.V. and G.V. Johnson. 1974. Some effects of subirrigation on bentgrass during heat stress in the field. Agron. J. 66: 526-530.

10. Liu, Chunhua, R.J. Cooper, and D.C. Bowman, 1998. Humic acid application affects photosynthesis, root development, and nutrient content. HortScience 33 (6): 1023-1025.

11. Marcum K.B., and C.L. Murdoch, 1990. Growth response, ion relations, and osmotic adaptation of eleven C-4 turfgrasses to salinity. Agron. J. 82: 892-896.

12. Rauthan, B.S., and M. Schnitzer. 1981. Effects of soil fulvic acid on the growth and nutrient content of cucumber (Cucumis sativus) plants. Plant Soil. 63:491-495.

13. Sladky, Z. 1959 a. The effect of extracted humus substances on growth of tomato plants. Biol. Plant. 1: 142-150.

14. Sladky, Z. 1959 b. The application of extracted humus substances to overground parts of plants. Biol. Plant. 1: 199-204.

15. Taiz and Zeiger, 1991. Plant Physiology. P.362-364. The Benjamin / Cummings Company, Inc.

16. Turgeon, 1996. Turfgrass Management (4th ed.). Regents/Prentice Hall, Englewood Cliffs, New Jersey.

17. Varshovi, A.A. 1991. Humate: properties and influence on the growth and nitrogen uptake of Bermudagrass. M.S. Theses. Univ. of Florida, Gainsville, FL.

18. Svedrup, H.V., M.W. Johnson, and R.H. Fleming. 1959. The oceans, their physics, chemistry, and general biology. Prentice Hall, Englewood Cliffs, N.J.

Transition Enhancement
Using Post-Emergence Herbicides

By D.M. Kopec and J.J. Gilbert, University of Arizona

Many turfed areas in the southwestern and southeast United States overseed bermudagrass turfs in early fall in order to provide year-round cover as functional turfs. Transition to bermudagrass in the spring is due to many factors which include irrigation, mechanical cultivation and bermudagrass condition shortly before or at the time of overseeding.

Persistency under close mowing and improved heat tolerance of perennial ryegrass germplasm can negatively affect transition, maintaining a prolonged and sporadic ryegrass cover that minimizes a normal bermudagrass growing season before the next overseeding.

This study deals with the use of select herbicides applied to overseeded bermudagrass in order to eliminate perennial ryegrass when bermudagrass is actively growing in the spring.

Materials and Methods

A two-year-old Tifgreen bermudagrass turf that was maintained at 7/32 inch height was overseeded in October at a rate of 22 pounds per 1,000 square feet on a sand-based rootzone at the Desert Turfgrass Research Facility, University of Arizona, Tucson. A perennial blend of VIP II was used. Plots were irrigated to prevent stress and were mowed three times a week. A total of six pounds of nitrogen per 1,000 square feet was applied to the turf between November 2 and May 13 as water soluble carriers or companion chelated iron complexes.

The first of two applications of herbicide were made on May 5. A CO_2 backpack sprayer with 8004 nozzles was used for a final spray volume of 66 gallons per acre. The second application was made on May 20. Single applications of Image were made at 0.25 pounds ai/acre and 0.38 pounds ai/acre. A group of plots received two applications of Image at 0.25 pounds ai/acre. Kerb was applied only in single applications at 0.5 and 1.0 pounds ai/acre.

The degree of transition was determined by counting the amount of perennial ryegrass tillers within the plots. Tillers were then tweezed apart to distinguish positive identification of the *Lolium perenne*. Plot sizes were 6 x 6 ft.

There was only a slight advantage to a second application of Image at the 0.25 pounds ai/acre rate.

Injury was rated by percent injury, degree of plot injury (1= least to 6 = most dense) and overall turf visual quality (1= dead grass to 9 = best). Verdure dry weights and shoot densities were taken as well from two four-inch cup cutter samples after mowing on June 10.

Test Results and Discussion

Based on measurements taken on May 19 and June 2, herbicide treatment was highly effective. On May 19, mean ryegrass density for untreated plots was 12.8 tillers per ring. This fell to 9.3 tillers per ring by June 2.

The Kerb plots ranged from 4.6 to 7.5 tillers per ring. The Kerb plots treated once at 1.0 pounds ai/acre had an average of 4.6 tillers per ring. Kerb plots treated once at 0.5 pounds ai/acre had a mean ryegrass density of 6.3 tillers per ring.

Image treated turf at 0.38 pounds ai/acre had 7.5 ryegrass tillers per ring. The turf treated once with 0.25 pounds ai/acre had 7.5 tillers per ring.

Ratings were performed again on June 2. This was after a second application of Image to some plots on May 15. Nevertheless, the plots receiving a single application of Kerb had the lowest amount of ryegrass. Both the 0.5 and 1.0 pounds of ai/acre Kerb plots did well, having had only 2.3 to 2.6 tillers per ring respectively.

There was only a slight advantage to a second application of Image at the 0.25 pounds ai/acre rate. The single application from May 5 had a mean ryegrass density of 5.9 tillers per ring, while the repeat treatment was 4.6 tillers per ring. The one-time treatment of Image at 0.38 pounds ai/acre had a mean ryegrass density of 4.1.

Agronomic Responses

Percent injury scores were taken on May 19, May 26 and June 2. On May 19, the scores ranged from 1 to 4.8. Kerb at the 1.0 pounds ai/acre rate had the highest injury on a percent plot basis. Kerb treated plots had the most noticeable injury symptoms of straw colored leaf tips and slight leaf cupping. It should be noted that the cupping and straw tipped leaves occurred on the underlying bermudagrass.

By June 2, the Kerb treatments showed an accelerated response, exhibiting increased turf injury. While the 1.0 pound ai/acre Kerb had a 42% mean turf injury, the 0.5 rate of Kerb had a 13% mean injury rate. The repeat application of Image at 0.25 pounds ai/acre had a 5% mean ploy injury.

At 28 DAT, the Kerb plots had poorer turf color scores, mainly from leaf tip burn and twisting and cupping of the bermudagrass.

Turfgrass color scores on May 19 ranged from 5.8 for treated turf to 7.2 for the untreated control. All treatments, except Kerb at the 1.0 rate, had color scores of 7.0. The higher rate of Kerb caused leaf tip burn and slight cupping.

Mean color scores for June 2 ranged from 4.0 for the high Kerb rate to 7.5 for the 0.38 pound ai/acre rate of Image. The mean of the control was 6.9. Kerb at the low rate had a mean color score of 5.0, due to straw colored lead tips, which predominated in the canopy. The repeat application of Image had a slightly lower color score compared to the single application at the same rate.

Shoot Density and Verdure: Visual estimates of turf densities were assigned to plots on May 19 and June 2. On May 19, Kerb treated plots had a slight decrease in visual density (5.8) at the 0.5 pounds ai/acre rate, followed by a more noticeable density loss at the higher rate. On June 2, the latent effects of the Kerb treatments were evident, with visual density scores at 4.3 and 3.0 for the lower and higher treatments respectively. Image treated turfs had density scores of 5.3, 5.5 and 6.0 for the single lower rate, double low rate, and higher rate respectively.

Shoot density counts were made of June 16 by harvesting two 4-in. cups per plot. Kerb treated plots had the lowest number of shoots at 83, while Image plots had between 100 and 104. The control plots averaged 104 shoots.

Verdure was taken immediately after plots were double-mowed on June 10. Verdure was removed with sharp clipping shears and oven dried. Verdure dry weight was not affected by herbicide applications.

Overall turf quality scores were assigned on May 19 andf June 2. Fourteen days after treatment (DAT), all treated turfs had slightly darker color that the control. At 28 DAT, the Kerb plots had poorer turf color scores, mainly from leaf tip burn and twisting and cupping of the bermudagrass.

Conclusions

- A repeat application of Image was more effective than a single application at the same rate, but not significantly better than the single application at the high rate.
- Kerb treated plots had greater injury and lower color scores, especially at the high rate.
- Kerb plots had decreased shoot density.

By D.M. Kopec, extension turf specialist, and J.J. Gilbert, turf research specialist at the University of Arizona, Tucson.

Take a look at the list below and you'll see a variety of interesting topics to be covered in upcoming issues of *TurfGrass Trends*. But one of the most interesting things happening in the field of turfgrass research won't be covered because it's still in a period of transition.

I'm talking about the resolution of the Family Quality Protection Act and possible limitations on the materials we use to manage our turf. This issue is huge to the manufacturers and end-users, but also huge to those whose ideas start everything rolling— turfgrass researchers.

It's still a guessing game about which products will continue to stay in the market and which will be withdrawn. The impending burden of new research, testing and retesting has made some manufacturers quail at the prospect. Surely, we'll see some familiar products go away and some new types of products enter our marketplace. I'm just hoping we don't see budgets for turfgrass research go away.

There's a saying in the marketing/advertising world that when you're successfully marketing a product and think you don't need to advertise, it's exactly the time you should be marketing. You have to build momentum, grow what you have and anticipate the next cycle of product change or sales growth.

I think the same holds true for turfgrass research. If some organizations are starting to feel that the research dollars might not justify themselves in the future, they should think twice. This is exactly the time to continue the work, build on the momentum established by the research of the past and anticipate changes to come.

Most of *TurfGrass Trends*' readers understand the value of turfgrass research and how important those research funds are, both in industry and academia. But do your customers, your greens committees, your employees, your neighbors? How about your Congressmen? Do your suppliers know how important these products are to you? If you think turfgrass research is something worth growing, it's the time to start talking about it and making sure we continue to invest in its future.

Sue Gibson

In Future Issues

- Grub Identification
- Nematode Biology
- Herbicide Resistant Turf
- Snow Molds
- High Tech Soil Amendments
- Beneficial Bacteria

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