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Inside This Issue Of Hole Notes

Upcoming MGCSA Events

July 17
BASF Fundraiser Tournament
Albion Ridges Golf Course, Annandale
Host Sup't: Brooks Ellingson

July 27
U of M TROE Center Field Day
U of M St. Paul Campus
Hosts: Dr. Brian Horgan
and Larry Vetter

August 7
MGCSA Championship
Windsong Farm Golf Club, Independence
Host Sup't: Scottie Hines, CGCS

September 18
Harold Stodola
Research Scramble
Medina Golf & Country Club, Hamel
Host Sup't: Drew Larson

October 9
MGCSA Fall Mixer
Oakdale, Golf Club, Buffalo Lake
Host Sup't: Mike Knodel

Advertisers

About the Cover

Captain Rob Adams *(and golf course superintendent at The Ponds at Battle Creek Golf Course in Maplewood)* returned from his tour of duty in Iraq and arrived safely in Minnesota on June 21st! Rob provided tremendous insight for MGCSA members in a series of articles in diary form published in *Hole Notes* over the past six months.

PRESIDENT'S MESSAGE

Whatever Your Philosophy in Life Try Not to Take it for Granted

By James Bade

If you are a shopper, I am sure you know about Marshall Fields Day. And if you are a summer goer in St. Paul, I bet you know about Grand Ole Day. But what if you are a turf manager in Minnesota? The U of Minnesota has Turf and Grounds Field Day. This year the date is Thursday, July 27. It is quite remarkable to see what Dr. Horgan, Eric Watkins and others have accomplished in a short amount of time at the TROE Center. When the event first started, I used to tend to the golf course while my assistants and gardener went. After attending the last two years myself it is an event I want to go to every year.

In 2004 I learned how iron might function in the grass plant. I learned which ornamental grasses that I would like to use in our prairie areas. There was a neat study about ET rates and how much you should water. What is really invaluable to have in our own back yard are the NTEP studies. The colonial grasses for fairways looked promising. But what really stuck out was a velvet bentgrass for greens. It looked like the best looking turf I had ever seen.

Last year the data on Phosphorus runoff was becoming quite interesting. Dr. Krischik was there to answer any questions we had about insects. (Plus she had a great book for sale at a great price.) And those velvets and colonials weren't as amazing as the year before. Rather, some other varieties were beginning to look quite promising. What a difference a year had made. It makes me wonder what the varieties are going to look like this year! The other benefit of Field Day is touching bases with fellow superintendents to see how their seasons are going and what is working for them. Come and show your support for Dr. Horgan and Dr. Watkins. I hope to see you there.

The quote of the day at Somerby Golf Club was, "I love to see bentgrass under stress." We had a great day of golf for the Scholarship Scramble. Casey Conlin and staff had the place in immaculate shape. What a tight stand of bentgrass they have. Things were firm and the south wind made for a wonderful test of golf. It was great seeing the golf course Casey talked about at the March mini-seminar. A lot goes into making a day like that special. So I want to thank all those who participated in one way or another from the grounds staff to those who played and the vendors who sponsor our events.

Time of reflection

When I heard the sad news about Katlyn Feriancek, I paused for a moment in heartbreak and sadness. Situations of losing loved ones like that puts everything into a proper perspective. Whatever your philosophy in life, try not to take it for granted. So I will close with a poem from Charlotte's Web while I hold my family and friends dearly.

"How very special are we, for just a moment to be, part of life's eternal rhyme.
How very special are we to have on our family tree mother earth and father time.
He turns the seasons around so she changes her gown but they always look in their prime.
They go on dancing their dance of everlasting romance mother earth and father time.
The summer larks return to sing, oh what a gift they give.
Then autumn days grow short and cold, oh what a joy to live.
How very special are we for just a moment to be part of life's eternal rhyme.
How very special are we to have on our family tree mother earth and father time."

Living a poem with you,
James

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HOLE NOTES

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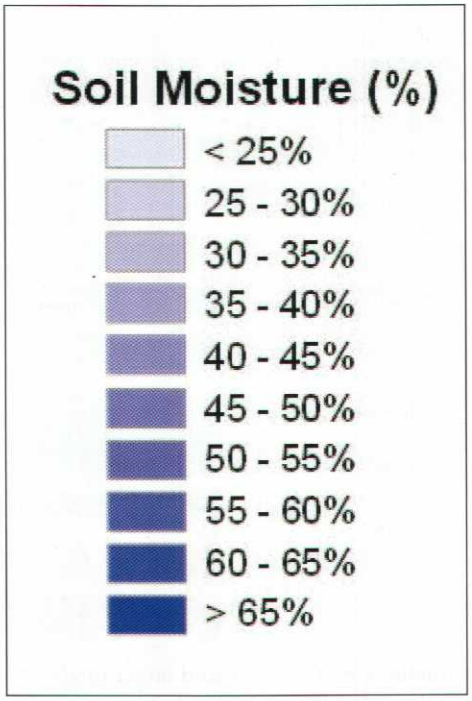
Site-based Irrigation Control:
Using Sensors to Assess Agronomic Conditions

By Van Cline, Ph.D.
Toro Co.

There's not much debate that water is the most important resource in growing quality turf. We can get by without a lot of other inputs, but we can't get by without water. It follows then that irrigation is the most important management practice. Irrigation management demands more attention and at times creates more anxiety than any other activity in a turf manager's routine. Inadequate water or a bad irrigation system can be the kiss of death.

Turf irrigation systems today are very sophisticated in their ability to distribute water efficiently. The industry has made great strides technologically over the past 20 years. We've developed low pressure systems, pressure compensation, low precipitation rate, matched precipitation rate and balanced precipitation rate heads, heads with variable arcs, more reliable valves, valves in heads and many other features that have improved system performance. Irrigation control is equally sophisticated. Water can be turned on and off automatically in a nearly endless combination of ways. We can control thousands of sprinkler heads on a golf course down to the individual head. We can communicate to satellites wirelessly. We can manually adjust individual head attributes to fine tune the way it waters. The list goes on.

The weak link in the irrigation process is the agronomic decision-making component. It's deciding where and when water is needed, how much should be applied and what type of cycling is necessary to optimize the amount that reaches the root zone. We know that better control over water equates to healthier turf. Optimizing soil moisture has benefits for the plant, the soil and play conditions. But historically we haven't had good tools to help make these decisions. And, the fact that the typical golf course has a tremendous amount of variability in soils, topography and microclimate makes it even more difficult to know precisely where water is needed and where it's not. Experience and observation over time along with some basic equipment like soil probes are all we've had to base adjustments on. So, the norm is to irrigate to keep the dry areas moist. No matter how much we manually adjust individual sprinkler heads or how much we adjust run times, we tend to end up with areas that are too dry and areas that are too wet. It amounts to a lot of trial and error for the turf manager who wants to fine tune his system. The lack of accurate information on which to base irrigation control has resulted in an industry-wide tendency to over-water.



Another concern that looms large for the turf industry is the pressure to reduce overall water use. Water is projected to be the resource issue of the century worldwide, both in terms of availability and quality. It's hard to imagine shortages in a water rich state like Minnesota, but water use restrictions are beginning to appear. The water situation will never be better than it is today, that's the reality. Water conservation is no longer an issue only in arid regions of the U.S. It's becoming an urban issue as well due to intense competition for limited supplies in densely populated areas. Because turf is an urban crop, it's an easy target for restrictions when supplies become limited. As a result, developing methods to more precisely control irrigation is necessary for two main reasons: 1) to grow the healthiest turf possible and 2) to conserve water in the process.

Site Variability

Precision irrigation is not possible without detailed information on the agronomic conditions that influence water dynamics on a site. Irrigation systems are designed to uniformly distribute water. The layout and spacing of sprinkler heads are the primary attributes that achieve uniformity. But the specific location of each sprinkler head in the landscape makes it unique. Uniformly applying water to the surface is one thing but getting it into the root zone and storing it uniformly for plant use is another. Once the water leaves the nozzle and hits the surface it's the specific set of site conditions within the arc of that head that determines the fate of the water. A carefully designed system that uniformly distributes water rarely produces a uniform supply in the root zone because of variation in conditions across the site. Until we understand the variability in those conditions and how the irrigation system is superimposed on the site there is no way we can optimize the irrigation scheduling to efficiently apply and store adequate water in the soil system. Precision irrigation therefore requires detailed information on the critical site conditions that influence water movement and storage. Collecting and analyzing this information requires a more technological and scientific approach to site assessment than we practice today.

So what are the critical conditions? Soil characteristics have the greatest influence on water availability. Soil texture, or the relative amounts of sand, silt and clay, determine in large part how a soil drains and how much water it can store. A coarse-textured, sandy soil drains quickly but holds little water, while a fine textured clay soil drains slowly but stores a larger volume of water. The organic matter content of a soil also influences moisture storage. The higher the stable

(Continued on Page 6)

Sensors–

(Continued from Page 5)

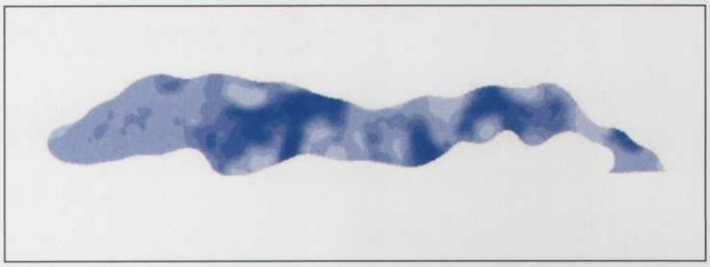
organic matter content of a soil (the darker the soil color) the more water it will hold. Texture and organic matter also determine a soil's fertility. Detailed soils information is invaluable in turf management but is rare. Analyzing and mapping soils is a tedious and expensive process. As a result, few golf courses have it. What complicates the soil situation further is the variability that typically occurs across a site. Soils form a continuum. There are rarely distinct boundaries between soil types which can, for all practical purposes, create an endless combination of soil conditions. It's not uncommon for golf course fairways, especially ones with significant topographic variation, to have significant variation in soils as well.

A second soil condition that significantly influences water dynamics is compaction. Fine-textured soils are generally more prone to compaction while sandy soils are more resistant. Compaction at the surface restricts water infiltration which can reduce the amount that makes it to the root zone, particularly if the compacted soils are on a slope. Compaction by definition reduces the amount of pore space that can hold water, so as compaction increases the amount of soil moisture available for root uptake is reduced.

A third factor that greatly influences water dynamics on a site is its topographic relief. In theory, water falling on a flat surface does not move. Water falling on a sloping surface runs off. Significant relief on a golf course fairway can cause tremendous movement and variation in where water ends up. Depressions and swales tend to be wetter while hilltops and slopes tend to be drier.

What really complicates the situation relative to water dynamics on a site are the interactions between factors. It's easy to visualize the influence of any one of the above site conditions on plant available water, but when you consider combinations of factors it gets much more complex. For example, water on a fine-textured soil subject to compaction on a slope acts differently than water on the same soil subject to the same compaction but on the flat. Or, soil moisture levels in a sandy soil with little compaction on a slope will be different than moisture levels in a medium-textured soil on a flat area subjected to cart traffic. On any given site not only can the variability within each specific site condition vary widely, but the number of combinations of conditions can make the situation mind-boggling. All this becomes important when you visualize a pattern of sprinkler heads overlaid on this site variability, and understand that each sprinkler head must be uniquely programmed to achieve maximum water use efficiency without compromising turf quality. Again, it becomes clear that the task of controlling irrigation to produce a high quality turf while conserving water is impossible without detailed site information.

So how do we get this kind of information? A lot of research and development has been done in what's called 'precision agriculture' to document site conditions in order to increase production by optimizing inputs. Similar R&D is being conducted in turf using a variety of sensors to capture important site data, and then mapping it using geographic information systems (GIS) for use by turf managers. Technologies now exist to collect and present the data in usable forms. Work is currently being done to develop systems and processes to do it cost effectively. All of the site conditions described above can now be measured and mapped to help turf managers make better irrigation decisions specifically and better management decisions in general. Here



are examples of the types of data that can be collected:

Soil Moisture

Soil moisture can be measured directly using a technique called time domain reflectometry (TDR) or indirectly using a technique called electromagnetic induction. Both can yield maps showing soil moisture variation across a site as illustrated above on two golf course fairways.

(Continued on Page 7)

Sensors–

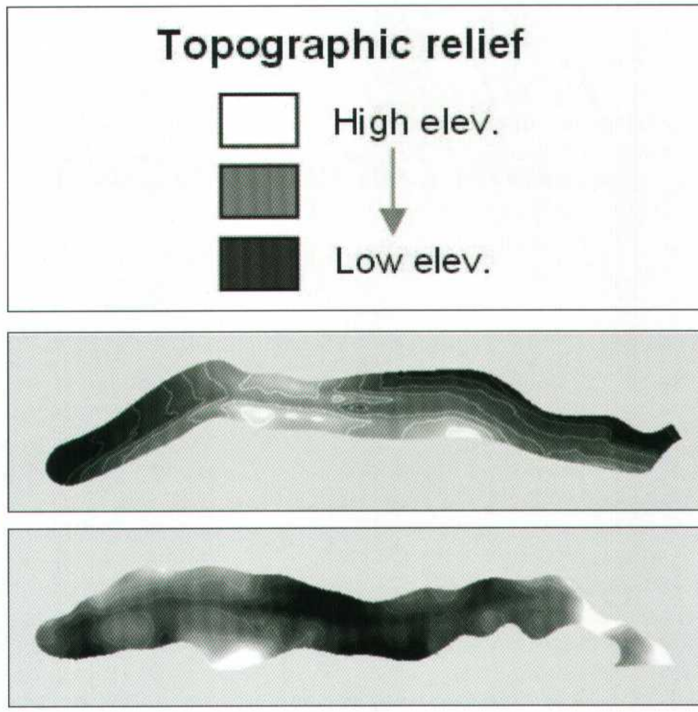
(Continued from Page 6)

Soil Compaction

Soil compaction can be measured by different types of instruments. The maps shown here were created from data collected by a device called a penetrometer which measures soil resistance to a probe being pushed into it. This type of information is useful in analyzing soil moisture variation, identifying causes of weak or stressed turf or in targeting aerification.

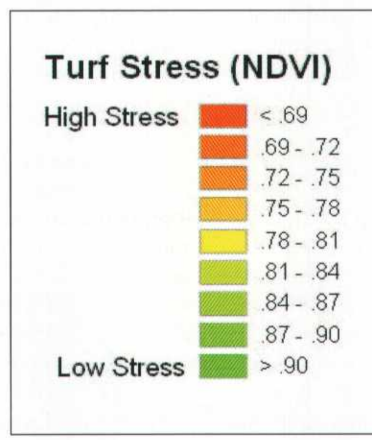
Topographic Relief

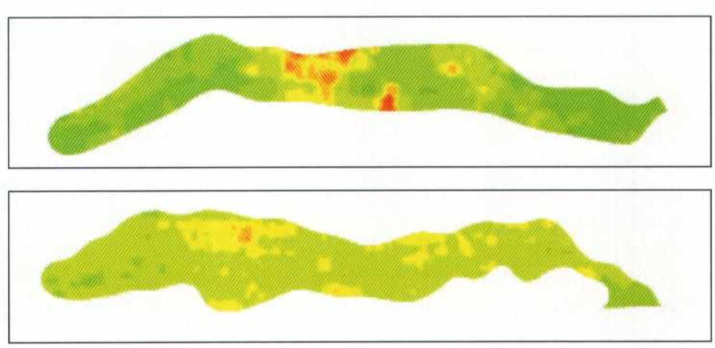
Some turf managers have topographic contour maps created using conventional techniques from aerial photographs. These topo maps are useful but the information is typically not available in a digital or computerized format. The maps at right were created from elevation data captured from GPS. GPS or global positioning systems not only provide two-dimensional location data (latitude and longitude) but also provide the third dimension or elevation data. GPS can map this data in a variety of ways including color contoured images showing relief from high to low or as conventional contour maps. When elevation data is digitized it allows much more flexibility in analyzing topographic conditions including slope steepness and slope orientation.



Turf Performance

Sensors exist that measure the characteristics of reflected light from a plant canopy to quantify the level of vigor or stress depending on your perspective. This data can then be used to generate maps. This technology has been studied for several years in agriculture and other plant applications, and is known to deliver reliable information on plant performance. Turf is an excellent application for the technology since the plant canopy is dense and uniform. The technology's strength is its ability to provide an accurate assessment of turf conditions quickly and automatically. Its primary limitation, however, is that it doesn't distinguish between causes of stress. Because the information is stored in a digital format it can be analyzed in a number of ways. Each mapping technique also creates an historical data base that allows the analysis of trends or changes in conditions over time.





IRRIGATION SCHEDULING ON SAND-BASED CREEPING BENTGRASS

Evaluating ET Estimation, Capacitance Sensors and Deficit Irrigation in the Upper Midwest

By J.F. Sass, M.S. Student, University of Minnesota, St. Paul
and B. P. Horgan, Assistant Professor, University of Minnesota, St. Paul

Abstract

During the 2003 and 2004 growing seasons, research was conducted on a 'Providence' creeping bentgrass (Agrostis stolonifera L.) sand green at the University of Minnesota St. Paul campus to evaluate the use of ECH2O capacitance soil moisture sensors and FAO 56 ET (Food and Agriculture Organization of the United Nations Evapotranspiration) estimation in scheduling turfgrass irrigation by applying prescribed irrigation treatments based on replacement of 100% actual ET loss and either 100% or 80% of FAO 56 estimated ET loss in a series of four 10 day experiments. Turf quality and soil moisture response to deficit irrigation treatments were also assessed. FAO 56 ET estimation accurately predicted actual ET, and a summer crop coefficient (kc) of 0.98 was calculated. ECH2O probes were highly sensitive to changes in soil moisture. There were no significant differences in root zone water storage fluctuation between treatments. Lysimetry and sensor data indicated the presence of a substantial thatch effect on irrigation infiltration and ET loss. Daily irrigation consistently wetted the soil no deeper than 10 cm. There were no statistical differences in turf quality between irrigation treatments in any experiment, suggesting that replacement of 80% of actual ET is sufficient to maintain acceptable daily irrigated creeping bentgrass in Minnesota.

Introduction

Water use in turfgrass culture is under intense scrutiny and has been identified by regulatory agencies and environmental groups as a focal point for reducing consumption of water. In addition to concerns over the scarcity of water supplies, the increasing monetary cost of water, electricity and irrigation system components are factors in the push for conserving water resources.

Carrow (6) identified efficient irrigation scheduling as one particular strategy that can conserve water resources in the management of turfgrass. Efficient irrigation scheduling reduces water waste by replacing only the amount of water lost to turfgrass use, or evapotranspiration (ET). To improve irrigation scheduling efficiency, various technologies are being evaluated by researchers as tools to augment or replace the art of irrigation.

Capacitance soil moisture sensors use the dielectric properties of soil to indirectly measure soil water content. Measurement of the frequency of an oscillating signal sent through a circuit (soil) yields an indirect measurement of soil moisture (13). Capacitance sensors are extremely sensitive to small changes in soil water content and are suitable for irrigation scheduling of citrus crops in the fine sand soils of Florida (8, 12). The suitability of capacitance sensing for scheduling turf irrigation, however, is not known.

Turfgrass water requirements can be accurately predicted by equations which use weather data to estimate ET (2). In contrast to soil moisture sensors, ET estimators are used widely to schedule turfgrass irrigation. Arizona (4) and California (14) currently use ET estimation as the basis for establishing irrigation scheduling guidelines for all agricultural and horticultural crops, including turfgrass. The Food and Agriculture Organization of the United Nations selected an updated version of the Penman-Monteith ET equation as the recommended single ET estimation model for crop irrigation and designated it FAO 56 (2).

In addition to efficient irrigation scheduling, Carrow (6) identified deficit irrigation as another important water conservation strategy. Many species of turf can be irrigated with less than 100% replacement of ET loss and maintain acceptable turf quality, resulting in substantial water savings (10). Creeping bentgrass (Agrostis stolonifera L.) specific deficit irrigation research is limited to DaCosta and Huang (7), who recently reported that replacement of 80% ET loss is adequate to maintain turf quality under fairway conditions in a sandy loam soil during the summer in New Jersey.

(Continued on Page 9)

Irrigation Scheduling–

(Continued from Page 8)

The objectives of this research were: evaluate the accuracy of FAO 56 ET estimation and develop a summer-use FAO 56 crop coefficient for creeping bentgrass turf in Minnesota; evaluate the response of ECH2O (Decagon Devices, Pullman, WA) capacitance sensors to changes in soil moisture by varying irrigation treatments and explore minimum ET replacement percentages and the possibility of using deficit irrigation strategies for creeping bentgrass turf in Minnesota.

Project Design

Six individual 5 m by 5 m plots were equipped with quarter circle spray heads on each corner and individual station at a satellite controller. Daily plot irrigation delivery accuracy relative to the target volume and Christiansen's coefficient of uniformity (16) of 70-90% was maintained and verified throughout each of four 10-day experimental periods by measuring individual plot irrigation input with three volumetric jars per plot.

The 35.6 cm deep root zone had a textural composition of 97.2% sand, 1.4% silt, and 1.4% clay, organic matter content of 1.9% (by weight), pH of 7.7, and C.E.C. of 2.0 meq 100 gm-1. Turfgrass cover was composed of 85-90% 'Providence' creeping bentgrass and 10-15% annual bluegrass (Poa annua L.). The thatch/mat was approximately 1.3 cm thick and did not significantly change for the duration of the project. During the experimental periods, daily mowing at 5 mm was performed in addition to the prescribed irrigation treatments by use of a walk-behind reel mower. Fertility was maintained outside of experimental periods at 14-day intervals at 4.8 to 9.7 kg N ha-1 yr-1; total fertility input for the plots was approximately 220 kg N ha-1 yr-1, 122 kg P2O5 ha-1 yr-1, and 292 kg K2O ha-1 yr-1. All other maintenance activities such as topdressing, verti-cutting and disease management were performed as needed and scheduled so as not to occur during experimental periods. Rainfall was eliminated by use of a polypropylene rain cover which could be installed within 5 minutes. Drainage losses or surface runoff into or out of the lysimeters did not occur as verified by leachate collection devices. Therefore, all water inputs were attributed to the prescribed irrigation treatments, and all losses were attributed to ET.

Three treatments consisting of daily irrigation inputs were replicated in triplicate and arranged as a randomized complete block design. Treatment A consisted of replacing 100% of lysimeter indicated ET loss, treatment B consisted of replacing 100% of FAO 56 estimated ET loss and treatment C consisted of replacing 80% of FAO 56 estimated ET loss. Experiments 1 (100% lysimeter vs. 100% FAO 56) and 2 (100% lysimeter vs. 80% FAO 56) were completed in August and early September of 2003 and replicated in July and August of 2004 as experiments 3 (100% lysimeter vs. 100% FAO 56) and 4 (100% lysimeter vs. 80% FAO 56). Preliminary work at the site indicated that the FAO 56 model closely predicted actual turf ET (data not shown). Therefore, 80% of the FAO 56 estimated ET was taken as equivalent to 80% actual turf ET.

Within each of the six plots, a free draining 19 L bucket-type lysimeter as described by Feldhake et al. (9) was installed and seeded during green construction in 1996. The lysimeters were level with and composed of an identical root zone mix as the surrounding turf. Lysimeter weight for each plot was measured twice daily, once immediately before irrigation and again immediately after irrigation, using an Ohaus (Pine Brook, NJ) I-20W digital scale. Following Aronson (3), change in lysimeter weight was correlated to a depth of water lost or gained. In this manner, both 24 hr ET loss and irrigation input (in mm) was calculated. Minimum detectable irrigation input was 0.2 mm.

Model EC-20 ECH2O capacitance soil moisture sensors were used to measure soil moisture within ±1% volumetric water content (?) with a resolution of 0.2%. Prior to the field experiments, soil specific sensor calibration (r2 = 0.98) was achieved by comparing triplicate measurements of known volumetric water content against the sensor output. One meter adjacent to the weighing lysimeter in each plot, ECH2O probes were inserted horizontally into the soil at 5, 10, 15, 20 and 25 cm depths in a spiral staircase pattern.

(Continued on Page 10)

Table 1.

Experiment	Date	FAO 56 ET (mm day^{-1})	Temp °C	RH (%)	Wind Speed (m sec^{-1})	Solar Radiation (W m^{-2})
1	Aug 2003	5.2	24.2	71.2	1.8	6550
2	Aug 2003	4.0	20.9	65.5	2.0	4997
3	July 2004	4.8	23.5	76.1	1.9	6301
4	Aug 2004	3.4	16.7	77.4	2.6	4671

Irrigation Scheduling–

(Continued from Page 9)

Triplicate plot TDR readings (mean of 0-11.7 cm soil depth) were recorded daily prior to irrigation using a Spectrum Technologies (Plainfield, IL) Field Scout TDR 300 soil moisture probe. Plot turf quality was rated at noon on days 1, 4, 7 and 10 of each experiment using a scale of 1 to 9 (1=dead, 6=acceptable and 9=ideal). Rating score was based on visible turf color, density and leaf texture.

Weather and class A pan evaporation data was collected from an automated on-site weather station. Average temperature, relative humidity, wind speed and solar radiation data was downloaded and software was used to generate FAO 56 ET estimates using the hourly step method (eq. 1) as described by Allen et al. (2):

(eq. 1)

Where ETo is the reference evapotranspiration (mm hour-1), Rn is the net radiation at the grass surface (MJ m-2 hour-1), G is the soil heat flux density (MJ m-2 hour-1), Thr is the mean hourly air temperature (°C), is the saturation slope vapor pressure curve at Thr (kPa °C-1), is the psychrometric constant (kPa °C-1), e° (Thr) is the saturation vapor pressure at air temperature Thr (kPa), ea is the average hourly actual vapor pressure (kPa), and u2 is the average hourly wind speed (m s-1).

Daily reference ET (ETo) was calculated by summing the predicted ET from each of the 24 hourly time steps. Preliminary analysis of the FAO 56 model on this site in June and July of 2003 showed good response to environmental conditions when regressed against actual turf ET, with crop coefficient (kc) values ranging from 0.85 to 1.05. Published FAO 56 specific crop coefficient data was limited to a suggested kc of 0.90-0.95 for all cool season grasses by Allen et al. (2). On the basis of the preliminary work on-site and the recommendation by Allen et al., a working crop coefficient of 1.0 was selected and used throughout the study period to yield the predicted turf ET (ETcrop) by the formula ETcrop = ETo * kc. Daily means of FAO 56 ET estimates, along with daily means of required weather data, are displayed in Table 1. The substantial differences in weather conditions and resulting ET demand among the four experiments meant that comparisons of treatment effects could be made within but not between experiments.

Table 3.

Experiment	Treatment	Mean Daily ET loss (mm)			Mean Daily Irrigation (mm)	
		Lysimeter†	FAO 56	ECH_2O sensor‡	Lysimeter†	ECH_2O sensor‡
1	100% Lysimeter	5.2	5.2	1.7	5.4	1.5
	100% FAO 56	5.1		2.1	5.0	2.0
2	100% Lysimeter	4.4	4.0	1.6	4.4	1.7
	80% FAO 56	3.8		0.8	3.3	0.7
3	100% Lysimeter	4.9	4.8	1.1	4.9	1.4
	100% FAO 56	5.0		1.4	5.0	1.4
4	100% Lysimeter	3.1	3.4	0.7	3.2	0.7
	80% FAO 56	3.0		0.7	2.8	0.5

† 0 to 28 cm depth
‡ 5 to 25 cm depth

FAO 56 ET estimation

Over the four experimental periods, FAO 56 ET estimation accurately predicted actual ET (r2= 0.84) (Fig. 1). The relationship between class A pan evaporation and actual ET was not as strong (r2 = 0.40). The daily mean computation procedure outlined by Brown et al. (5) yielded an FAO 56 mean crop coefficient of 0.98 (standard error of 0.02) and a class A pan evaporation coefficient of 0.81 (standard error of 0.04).

Lysimeter indicated irrigation inputs were not significantly different in experiments 1, 3 (100% lysimeter ET vs 100% FAO 56 ET), or 4 (100% lysimeter ET vs 80% FAO 56 ET). In experiment 2, 80% FAO 56 ET irrigation inputs were significantly lower than 100% lysimeter ET irrigation (Table 2).

The 10-day treatment mean of irrigation delivery accuracy was within ±4% of the target volume for each treatment in each experiment (Table 2). The deficit irrigation treatments in experiments 2 and 4 were 83 and 82%, respectively, of FAO 56 estimated ET.

The differences in daily mean lysimeter measured ET between treatments were within 0.1 mm day-1 in experiments 1, 3, and 4. Daily mean lysimeter measured ET for 80% FAO 56 irrigated plots was 0.6 mm day-1 lower than 100% lysimeter irrigated plots in experiment 2 (Table 2). However, none of the differences in lysimeter ET was significantly different.

Turf quality ratings remained above acceptable levels and were not significantly different between treatments at either the start or end of each experiment. There were also no significant changes in turf quality from day 1 to day 10 in any treatment during each experiment (Table 2). This suggests that daily deficit irrigation scheduling which seeks to replace 80% of actual ET is sufficient to maintain turf quality of creeping bentgrass for at least 10-day periods during the summer in Minnesota.

Table 2.

Experiment	Date	Irrigation Replacement Treatment		Mean Lysimeter Measured ET ($mm\ d^{-1}$)	Mean Lysimeter Measured Irrigation ($mm\ d^{-1}$)	Turf Quality (d1) (1-9)	Turf Quality (d10) (1-9)	
1	8/8 - 8/17/2003	100% actual ET		5.2†	5.4	7.0	6.9	NS‡
		100% FAO 56 ET		5.1	5.0	6.8	6.8	NS
			LSD	NS	NS	NS	NS	
2	8/25 - 9/3/2003	100% actual ET		4.4	4.4	6.9	7.0	NS
		80% FAO 56 ET		3.8	3.3	6.8	6.1	NS
			LSD	NS	0.90§	NS	NS	
3	7/13 - 7/22/2004	100% actual ET		4.9	4.9	6.6	6.2	NS
		100% FAO 56 ET		5.0	5.0	6.6	6.3	NS
			LSD	NS	NS	NS	NS	
4	8/9 - 8/18/2004	100% actual ET		3.1	3.2	6.4	6.2	NS
		80% FAO 56 ET		3.0	2.8	6.7	6.3	NS
			LSD	NS	NS	NS	NS	

† Data presented are grand means of daily means by treatment within each 10 d experiment.
‡ *NS*, nonsignificant at the 0.05 level.
§ Fisher's LSD values are reported where significant differences at the 0.05 level occur.

(Continued on Page 11)