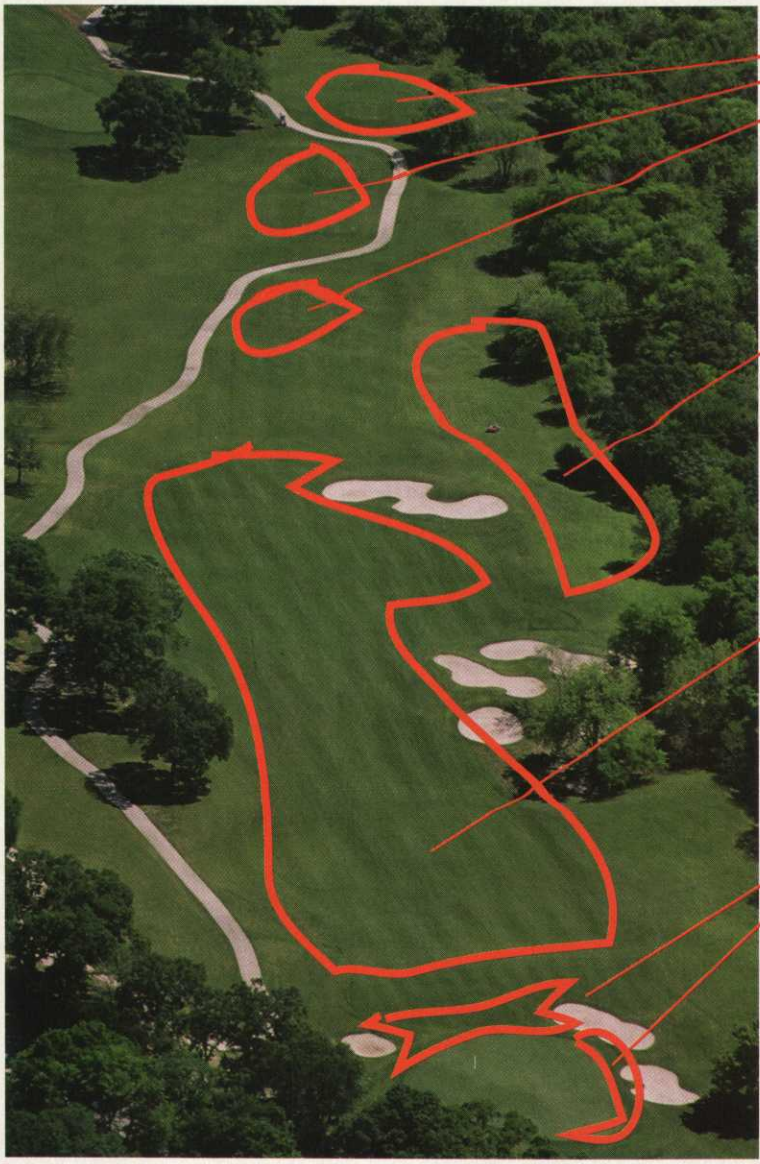
Any Way You Cut It, TifSport Can Stand Up To Frequent Lower Mowing Heights.



TEES: 3/8"

Thanks to TifS[port's superior turf density, sod strength and good lateral growth rate, it's perfect for high traffic areas like tees. It also shows improved resistance to and quick recovery from divot injuries.

ROUGHS: 1-1/2"

You can maintain a good TifSport rough of up to 1-1/2", so why not stick with the same grass you have on your tees and fairways? You'll really be cutting down on your management headaches.

FAIRWAYS: 5/8"

TifSport's leaf blade orientation and stiffness make it ideal for fairways. A lot of superintendent's are hearing from golfers that TifSport gives a better ball lie than other bermudas.

SURROUNDS: 3/8"

TifSport has just what it takes for a perfect landing area. It holds good shots and it's tough enough to take lots of shots without injury. No wonder more and more superintendent's are using TifSport on their greens collars.

Unlike many bermudagrass varieties, TifSport can handle a wide range of mowing heights. That's why it's so ideal for tees, fairways, roughs and approaches. Wall to wall TifSport. Talk about a superintendent's dream. TifSport also recovers very quickly from injury, has excellent cold-tolerance, color, texture, and density, as well as improved pest resistance. And while it might green up a little later than some bermudas come spring, once it takes off it's very aggressive. A lot of superintendents feel this is a big plus when they're dealing with fluctuating spring temperatures. TifSport. Specify it by name for your new course or renovation project.

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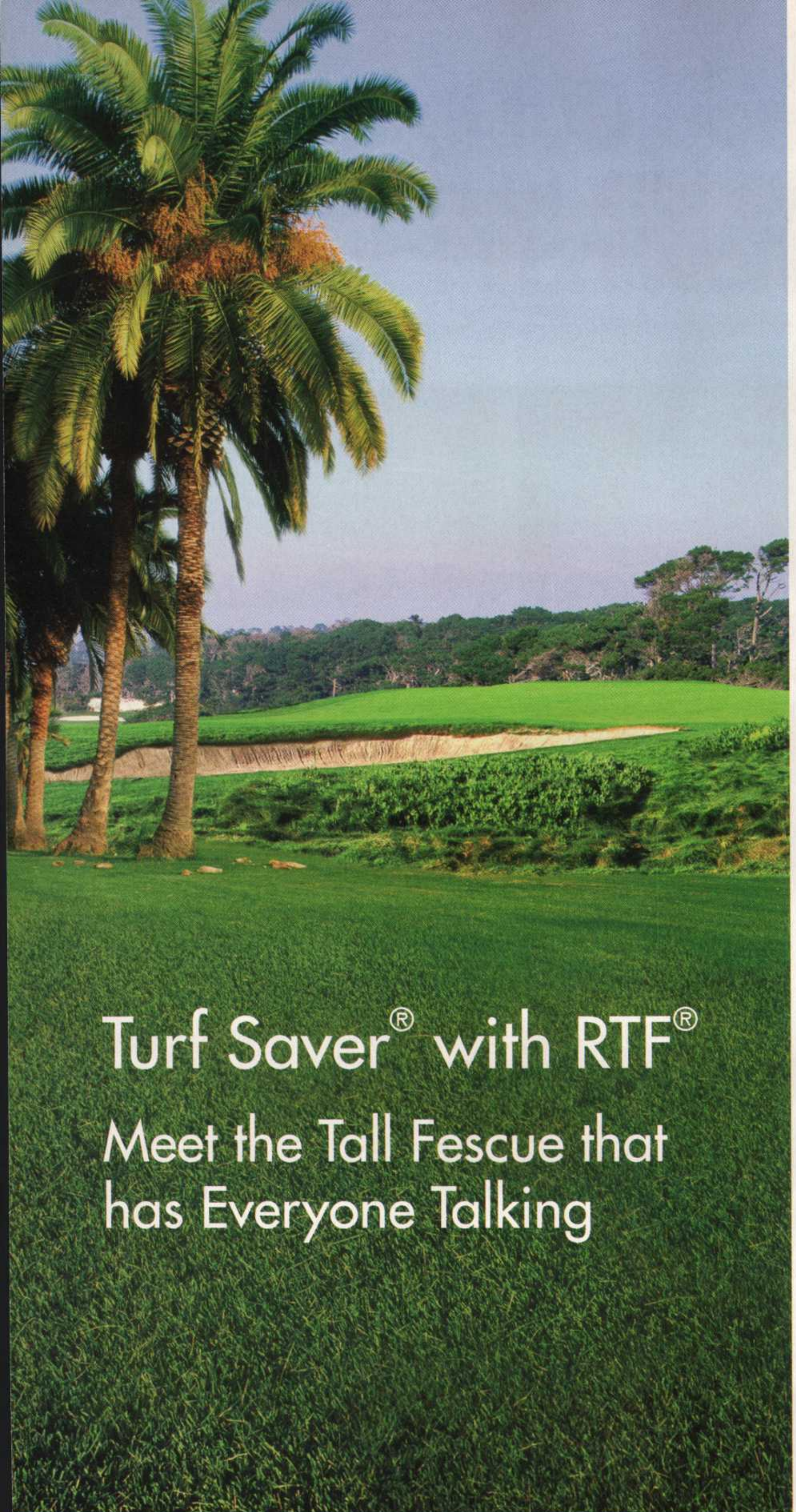

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IRRIGATION

The Big Dig

Nanotechnology gets to root of soil moisture

By Mohamed Saafi, Paula Wade, Peter Romine and Tommy Coleman

An important goal in golf course management, sports turf maintenance or any agricultural endeavor is to optimize the use of natural resources, namely water supply in irrigation systems.

Irrigation management systems should have information about soil moisture at the root level of plants. With such information, irrigation water could then be provided in a more efficient way.

Today a large number of sensors based on different methods are available to measure soil moisture and temperature. However, they present one or more of the following drawbacks: inaccuracy, high cost and soil dependency. Meanwhile, nanotechnology-based sensors can be considered a serious replacement to current monitoring systems due to their inherent advantages, namely low cost, high reliability and wireless sensing capability.

The following research project explores the feasibility of using nanotechnology-based MicroElectroMechanical Systems (MEMS) sensors for soil moisture monitoring.

MEMS sensor

As shown in Fig. 1, the MEMS sensor consists of four microcantilever beams capable of measuring temperature and moisture in concrete material simultaneously.

The MEMS sensor is based on a shear stress principal for measuring water vapor, in which the microsensor chip combines a proprietary polymer sensing element and Wheatstone Bridge piezoresistor circuit to deliver two DC output voltages that are linearly proportional to relative humidity (RH) from 0 percent to 100 percent RH full scale and to temperatures from minus-30 degrees Celsius (C) to 100 degrees C.

A water vapor-sensitive nanopolymer film PVA (PolyViol G 2810) is bonded to the top of each cantilever beam and designed to expand and contract during exposure to water

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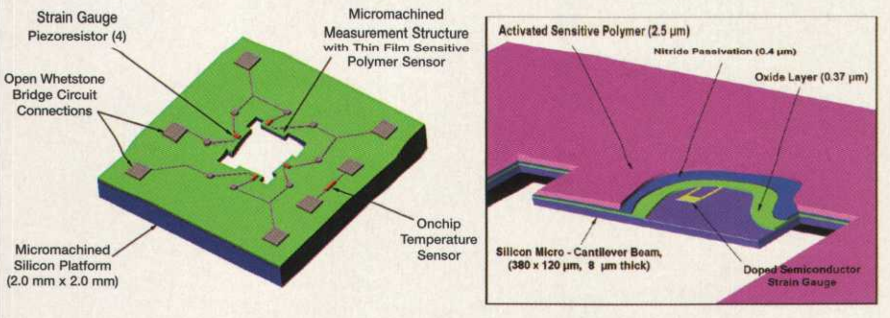
FIGURE 1

Typical MEMS for temperature and moisture sensing



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vapor. During sensor operation, ambient water vapor molecules in the material absorb into the sensing film surface. They are held by weak van der Waals forces because of the polar nature of water molecules. The water molecules continue to form polar bonds with various radical groups of the polymer molecules within the film.

All of the free surfaces of the film displace parallel and normal to the adjacent microbeam surfaces, with the exception of the film surface that is bonded to each cantilever beam. The bond constrains this film surface and prevents it from displacing. This constraint, known as a full shear constraint, produces shear stresses at the film/beam interface that cause the cantilever beam to deflect.

This deflection is measured as resistance change in the embedded strain gauges, and is linearly proportional to the shear stress.

Manufacturing process

The manufacturing of micro-machined MEMS sensors was performed using a combination of standard and customized semiconductor processing steps. Manufacturing begins with standard Complimentary Metal Oxide Semiconductor (CMOS) processing steps.

Typical CMOS steps performed on the wafer include chemical vapor deposition (CVD), oxidation, doping, diffusion and metallization. Photolithography and chemical wet-etching are used to pattern and form the silicon platform and measurement structures of the sensor.

A hybrid CMOS process is performed to deposit, pattern and activate sensing elements. The bridge excitation for these MEMS is provided by a 1.2V DC voltage source that's external to the sensor chip. As shown in Figure 2, the chip was encapsulated with ceramic jackets that were equipped with a ceramic filter for sensing purposes.

The sensor was calibrated and then embedded into soil samples to evaluate its response. It exhibited constant temperature output, attributed mainly to room temperature constant at 20.5 degrees C. However, the moisture output remained constant for a period of six days because of a high moisture level in the soil. Then the output began to decrease as the soil dried out.

The ultimate objective of this research is to develop a wireless network for field application, where thousands of sensor nodes will be used to monitor soil moisture and temperature.

Figure 3 shows a typical sensor network, where the sensors will be communicating with each others to remotely monitor the sensors response. The device will be packaged to form a sensor probe. The probe will be equipped with a box containing microprocessing, memory, backup battery and a communication system. The probe also contains a solar power energy harvesting and a two-way communication antenna.

FIGURE 2

Packaged chip

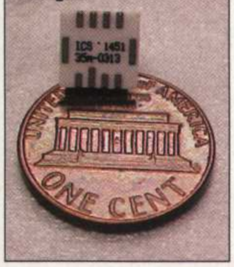
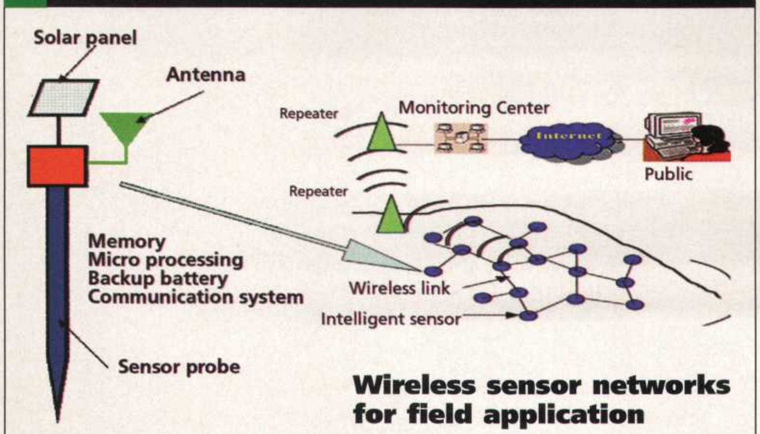


FIGURE 3



Wireless sensor networks for field application

Conclusions

In this preliminary research a low-cost nanotechnology-based moisture and temperature sensor was developed. Preliminary results indicated the developed device can monitor temperature and moisture with high resolution. Work is in progress to develop a wireless network for filed application.

Dr. Mohamed Saafi is an assistant professor and director of the Center for Transportation Infrastructure Safety and Security at Alabama A&M. His research interests include nanotechnology, wireless communication and remote sensing. Dr. Peter Romine is a chair of the engineering and technology department at Alabama A&M University. His research interests include nano and microtechnology, sensors and actuators, experimentations, and remote sensing. Paula Wade is an undergraduate student at the department of electrical engineering technology at Alabama A&M University. Her research interests include remote sensing and experimentation. Dr. Tommy Coleman is a professor and director of the Center for Hydrology, Soil Climatology and Remote Sensing. His research interests include remote sensing, soil science and GIS applications.

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Forget Milk. Got Water?

Evapotranspiration estimation, *in situ* sensing headline technological advances

By Jon Sass and Brian Horgan

Irrigation of turfgrass is increasingly targeted by regulatory agencies and environmental groups across the United States as a focal point for reducing consumption of water. As a perceived "luxury" crop, the turfgrass industry can expect to bear the brunt of further water restrictions and increased costs associated with irrigation.

Turf irrigation practices based on habit or observation of qualitative criteria such as color can lead to overwatering, wasting valuable water resources in addition to causing or exacerbating a wide range of turf problems (Archambeau, 2003; Carrow et. al., 2002a and 2002b).

Clearly, the health of your turf and even your bottom line as a money manager depend on delivering only the amount of water your turf needs: no more and no less. How much should we water on a given day? Let's backtrack for a moment and revisit a basic hydrologic equation depicting a balanced water budget where the inputs match the outputs:

inputs (irrigation + precipitation) = outputs (runoff + internal drainage + ET)

Evapotranspiration (ET) is a combination of the physical process of evaporation and the biological use of water by plants, known as transpiration. These two processes are tied together in their response to climate factors. So as long as irrigation inputs are not applied in sufficient volume to cause surface runoff or deep infiltration (past the root zone) losses, efficient irrigation scheduling boils down to replacing only the amount of water lost to ET:

irrigation = ET

How can technology help turf irrigators conserve water? If we can directly measure the moisture status of the soil using sensors, or indirectly measure soil moisture loss via ET estimation, we know exactly how much irrigation to apply. Because of cost, reliability and soil variability, moisture sensors are rarely used to direct irrigation of turfgrass. However, the rising operating costs of irrigation, along with the availability of affordable technological advances in electronic circuitry, software and wireless communications, are making soil moisture sensors a viable component of future irrigation management BMPs.

In contrast to soil sensors, simplified ET estimators have seen widespread use as aids in scheduling turf irrigation. Many irrigation management software programs currently in use at golf courses and athletic fields have an ET feature which predicts water loss and automatically controls how much water is delivered.

Although all ET equations provide estimates based on climate factors, they are not all equally applicable to turf situations. FAO 56, derived from the Penman-Monteith equation, is the current standard for ET estimation in cropping systems adopted by the Food and Agriculture Organization of the United Nations (Allen et. al., 1998) and was selected for use in this study.

Materials and methods

During 2003 and 2004, experiments were conducted at the University of Minnesota on a California-style sand creeping bentgrass green. Our objectives were threefold:

1. Evaluate the response of ECH_2O capacitance sensors to changes in soil moisture by applying various daily irrigation treatments (ECH_2O is Decagon's product name for its environmental capacitance product.)

a) 100-percent replacement of lysimeter-indicated ET loss (control);

b) 100-percent replacement of FAO 56 estimated ET loss; and

c) 80-percent replacement of FAO 56 estimated ET loss.

2. Evaluate the accuracy of FAO 56 ET estimation (theoretical loss) by comparing against weighing lysimetry (actual loss).

3. Develop FAO 56 crop coefficients for creeping bentgrass turf in Minnesota.

The green was divided into six 15-foot by 15-foot plots, each of which had the following installed:

Weighing lysimeter: A 5-gallon bucket containing soil and turf that was flush with the surrounding surface and could be removed from the green and weighed. The lysimeter gained weight after irrigation or precipitation events, and lost weight slowly throughout the day as a

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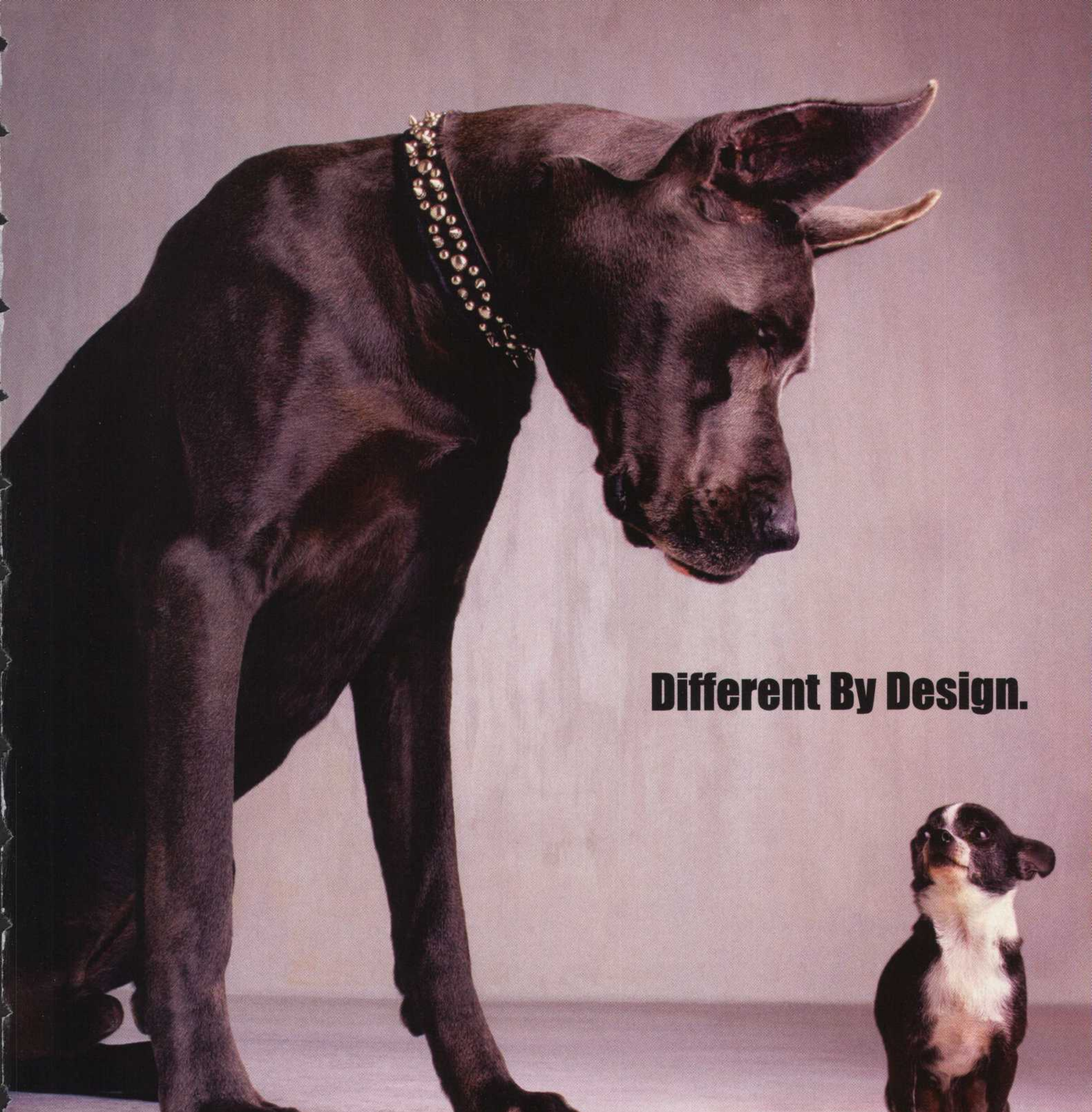

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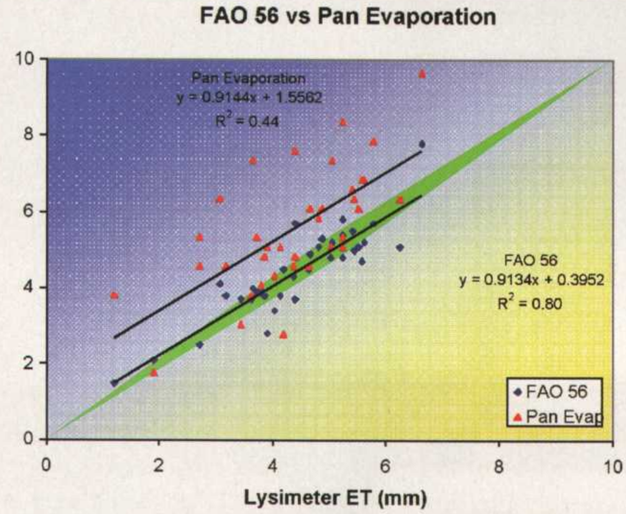
FIGURE 1



Comparison of FAO 56 and pan evaporation ET estimates against lysimeter measured ET over the four experimental periods. The green line signifies lysimeter ET.

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result of ET loss. Lysimeter weight change was converted to a depth of water lost or gained in millimeters (mm) (Aronson et. al., 1987), and accounting for any internal drainage, weight loss over a 24-hour period was accepted as the actual ET loss in mm/day for each plot.

Five ECH_2O 20 centimeter (cm) sensors were inserted horizontally into the soil at 2-, 4-, 6-, 8- and 10-inch (5-, 10-, 15-, 20- and 25-cm) depths, which allowed tracking of the wetting front by depth. The sensor cables, connected to data loggers off the putting green, were buried to allow normal maintenance practices.

Independent irrigation: Each plot had a separate station on the LTC controller used to irrigate the plots. Individual plot irrigation uniformity ranged from 70 percent to 90 percent throughout each study period.

Climate data, including hourly averages of solar radiation, temperature, humidity and wind speed were downloaded daily from an onsite weather station and entered into software to generate FAO 56 ET estimates. The six plots were randomly divided into three replications of two irrigation treatments for each of a series of four 10-day experiments.

Turf quality on each of the six plots was rated four times per experiment on a 0-9 scale with 0 being dead turf, 6 being minimally acceptable, and 9 being ideal. Data was statistically analyzed using the multivariate analysis and repeated measure functions in SAS (SAS Institute, 1998).

Results

Turf quality was not significantly different between treatments in any of the experiments.

Comparing pan evaporation and FAO 56 ET estimates to lysimeter ET over the two-year study period shows a strong relationship between FAO 56 estimated ET and lysimeter ET (R^2=0.80). Trend lines reveal that pan evaporation consistently overestimates actual ET, while FAO 56 appears to overestimate ET on low loss days and underestimate ET on high loss days. (Figure 1)

ECH_2O sensors recognized changes in soil moisture because of the irrigation treatments (Figure 2). ECH_2O probe sensitivity was high with extremely low variation in individual sensor response. All 30 of the originally installed sensors have performed without failure for at least two full years.

Sensor data indicates temporal trends which vary with depth and treatment. Daily replacement of 100 percent of lysimeter ET seems to maintain consistent soil moisture at the 5- and 10-cm depths over a 10-day period, with a slight downward trend at 15 cm. Daily replacement of 80 percent of FAO 56 ET seems to maintain consistent soil moisture at the 5 cm depth over a 10-day period, with slight downward trends at 10 cm and 15 cm, which indicates a difference in wetting depth between the two treatments.

This research indicates that Decagon ECH_2O capacitance sensors are sensitive and accurate enough to aid in efficiently delivering irrigation to managed turfgrass. These sensors could also be integrated into a feedback loop with future irrigation management software programs (Bremer, 2003).

FAO 56 ET estimation also shows great promise in maximizing irrigation scheduling efficiency using readily available climate data. Some current irrigation management software using other forms of ET estimation with varying success have been met with skepticism by many turf managers; FAO 56 represents an excellent opportunity to incorporate accurate ET estimation into irrigation scheduling by a broad range of end users from homeowners to superintendents.

Both of these technologies have the potential to serve as the foundation for future automated irrigation management, which can conserve water resources while maintaining turf quality.

Sensor data and turf quality ratings from the

Bayer Environmental Science

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An excellent transition aid, Revolver herbicide selectively removes cool-season grasses from warm-season grasses. Use it to control clumpy ryegrass, *Poa annua*, goosegrass and a number of other weeds in bermudagrass greens, teeboxes, collars and approaches surrounding bermudagrass greens, fairways and roughs. Results are generally apparent within one to two weeks.