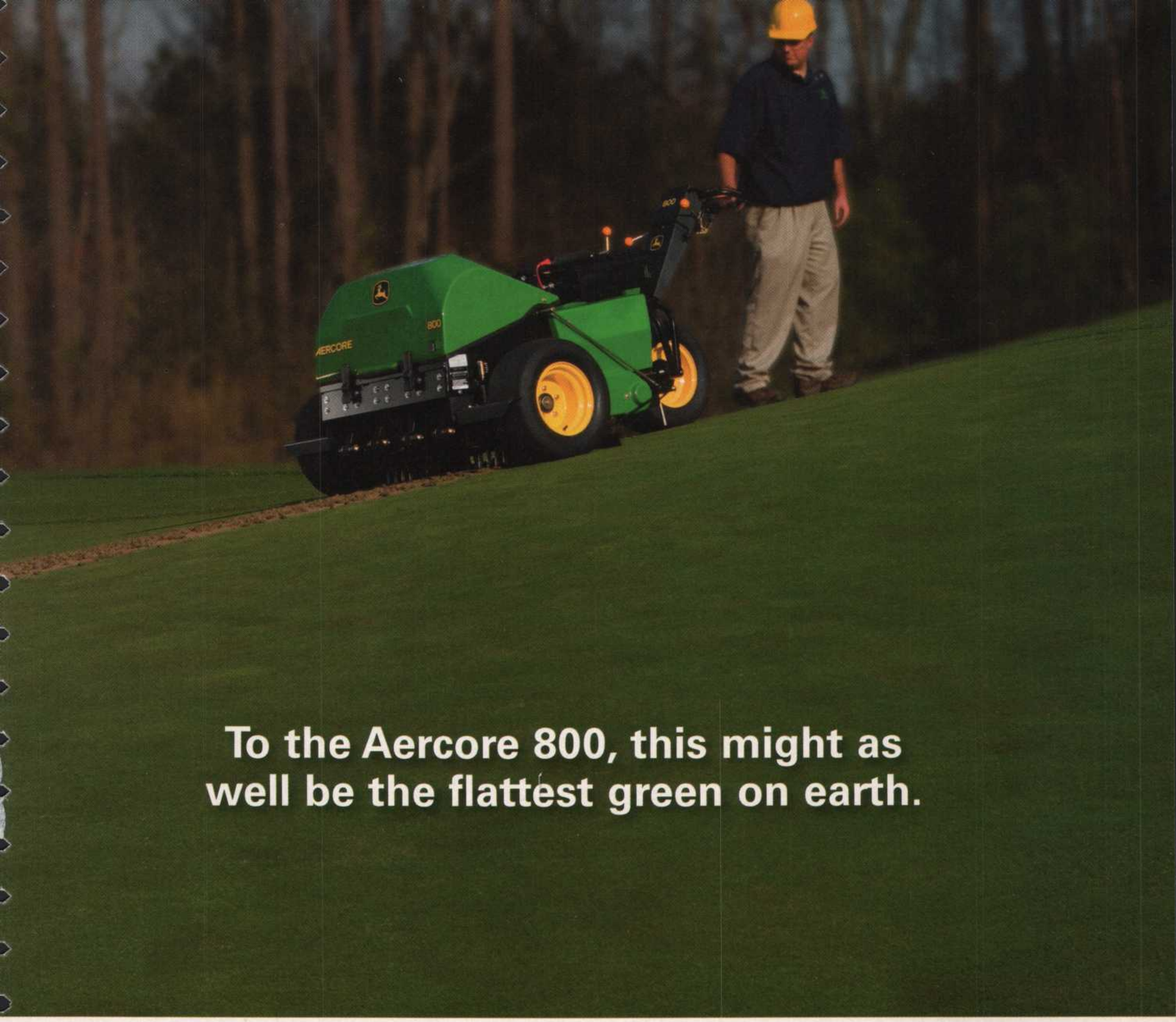

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TABLE 2

Coefficient of determination for regressions of nitrogen concentration, biomass production, chlorophyll concentration and visual quality of creeping bentgrass regressed on normalized difference vegetation index (NDVI), infrared/red (IR/R), Stress1, Stress2, spectral reflectance at 550 nm (WL550) and spectral reflectance at 710 nm (WL710) in Gilbert, Iowa, in 2002-2003.

Calibration	NDVI†	IR/R‡	Stress1§	Stress2	WL550#	WL710††
	2002					
Nitrogen concentration	0.23	0.32	0.58	0.51	NS‡‡	0.16
Biomass production	0.35	0.24	0.25	0.17	0.28	0.30
Chlorophyll content	0.32	0.26	0.29	0.29	0.20	0.19
Visual quality	0.54	0.71	0.71	0.67	0.25	0.32
	2003					
Nitrogen concentration	0.63	0.48	0.63	0.68	0.16	0.39
Biomass production	0.34	0.23	0.27	0.35	NS	0.16
Chlorophyll content	0.15	0.22	0.24	0.16	0.34	0.30
Visual quality	0.40	0.45	0.54	0.44	0.43	0.38

† Normalized difference vegetation index (NDVI) = (R800 - R600)/(R800 + R600)

‡ Infrared/red (IR/R) = (R780/R600).

§ Stress1 = (R706/R760).

¶ Stress2 = (R706/R813).

WL550 = R550.

†† WL710 = R710.

‡‡ Not significant (NS)

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during both 2002 and 2003 due to increased chlorosis and low plant density (Table 1).

While the 0.25 pounds per 1,000 square feet every 15 days N treatment resulted in acceptable quality during 2002 and 2003, the 0.5 pounds per 1,000 square feet every 15 days N treatment yielded the highest quality and chlorophyll concentration characterized by a dense, dark green turf canopy (Table 1).

No relationships were observed between WL550 or WL710 and the nitrogen concentration, biomass production, chlorophyll concentration or visual quality. This contradicts the results of Shepers et al. (1996) who reported that reflectance centered on 550 nanometers (nm) and 710 nm yielded some of the best relationships with N deficiency in corn. The best relationship between IR/R, Stress1 and Stress2 vegetation indices when regressed against visual quality was observed during 2002. These results were similar to those reported by Trenholm et al. (1999b) in a study conducted on seashore paspalum and bermudagrass. In comparison, NDVI, Stress1 and Stress2 produced the strongest relationship with the N concentration in 2003, while yielding comparably weak results during 2002 (Table 2).

Similar limitations in the consistency for NDVI predictions of N concentration have been reported by Bronson et al. (2005) in cotton (*Gossypium hirsutum L.*) grown under varying N rates. The strength of a remote sensing system will be judged by its reliability throughout the growing season. Basing management decisions on NDVI would require recalibration of the model for each sampling date against a well-fertilized control to ensure reliable results. While this might be possible in turfgrass management systems, it may not always be practical.

Analysis of the reflectance (r) data by partial least squares (PLS) regression canopy reflectance data in 2002 and 2003 yielded better predictive tissue N concentration results based on maximum r2 and minimum standard error of prediction (SEP) values than were observed for the vegetation indices (Table 3).

The results for the PLS regression in 2003 indicate a slightly weaker relationship between the actual and predicted N concentration in the tissue than was observed during 2002 (r2 = 0.71 vs. 0.95) (Table 3).

This may be explained by reduced uniformity in plot quality that resulted from localized dry spots that were present in several of the plots for a limited amount of time in 2003. In comparison to the other vegetation indices evaluated in this study, PLS regression yielded a stronger relationship between the actual and predicted N concentration across all dates in 2002 and 2003, indicating the potential benefit in using it to develop models for future remote sensing systems.

Continued on page 54

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TABLE 3

Partial Least Squares (PLS) regression statistics for estimation of nitrogen concentration, chlorophyll concentration, biomass production and visual quality for creeping bentgrass in Ames, Iowa, during 2002 and 2003.

Calibration	No. of factors†	r^2	SEP‡	*N*
	2002			
Nitrogen concentration (g kg-1)	8	0.95	1.51	60
Biomass production (g m2 d-1)	5	0.56	0.80	60
Chlorophyll concentration (µg g-1)	6	0.12	66.59	60
Visual quality	3	0.76	0.71	60
	2003			
Nitrogen concentration (g kg-1)	4	0.76	2.85	48
Biomass production (g m2 d-1)	3	0.64	0.66	48
Chlorophyll concentration (µg g-1)	2	0.02	98.72	48
Visual quality	2	0.65	0.90	48

† The number of factors necessary to achieve a minimum global standard error of prediction for the final partial least-squares regression model.

‡ Standard error prediction (the average difference between the actual values and predicted values of samples not used to develop the equation).

Continued from page 52

Much of the current technology that is readily available works quite well at identifying stressed areas in plant communities. With continued work, there may come a day when we will be able to rely on a remote sensing system to correctly identify specific nutrient deficiencies in turfgrass systems.

Until then, we can begin by using the remote-sensing systems as tools which can help pinpoint stressed areas, which can then be further investigated and diagnosed to maintain optimum turfgrass health and quality.

Jason Kruse, Ph.D., is the commercial horticulture educator for University of Wisconsin Extension-Winnebago County.

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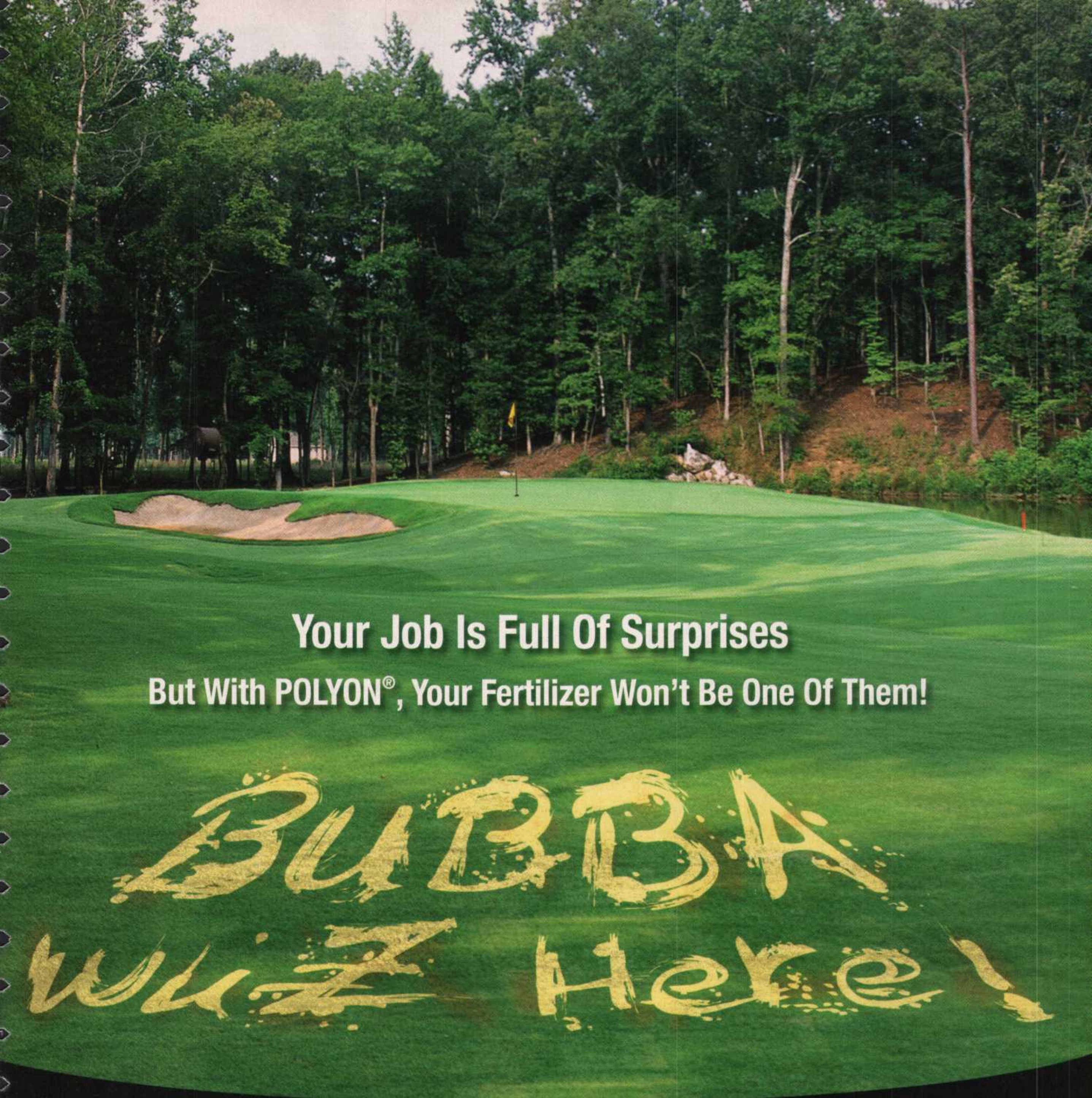

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PRG's Effect on Root Growth

By Jeffrey S. Beasley and Bruce E. Branham

Plant growth regulators (PGRs) are often applied to highly managed, cool-season turfgrasses every few weeks throughout the growing season to reduce clipping production, increase sward density, reduce seedhead formation and enhance sward color (Lickfeldt et al., 2001). Because PGRs reduce vertical shoot growth, some investigators have theorized that root growth may be enhanced through basal photoassimilate transport (Kaufmann et al., 1983).

Studies evaluating PGR application on turfgrasses have generally focused on shoot growth rather than root or whole plant growth. Extensive research has shown Primo reduces clipping production while increasing sward density for both warm- and cool-season turfgrasses (Ervin and Kioski, 1998; Fagerness and Yelverton, 2000). More detailed investigations of PGR application have found changes in shoot morphology, including increased cell density per leaf, shorter and thicker cells and increased specific leaf weights (Ervin and Kioski, 2001; Gaussoin et al., 1997; Heckman et al., 2001).

Because PGRs alter leaf morphology, the question remains: Do PGRs affect root growth and architecture?

Studies that have measured PGR effects on root growth have reported increased, decreased and no change in root mass (Ervin and Kioski, 2001; Fagerness and Yelverton, 2001; Marcum and Jiang, 1997). Far fewer studies have been conducted to assess PGR effects on turfgrass root characteristics such as surface area, root diameter and root length (Marcum and Jiang, 1997).

Root mass measurement alone does not provide the details necessary to understand the effects of PGR application on plant root growth and structure. More complete information regarding rooting characteristics such as total root length, average root diameter and root surface area provides researchers the insight needed to evaluate the effect of a factor (temperature, water availability, pesticide applications) on root structure. Time again it has been shown root structure plays an integral role in determining a plant's ability to obtain water and nutrients for proper plant growth and development.

Additionally, when considering the effects of PGRs or other growth modifiers, researchers have tended to examine shoot growth without consideration for root growth, or conversely, measured root mass without considering shoot-growth parameters. Particularly when studying compounds that modify plant growth, such as PGRs, it is imperative that both shoot and root responses be examined in order to understand how these compounds affect total plant growth.

The objective of our research was to determine the effect of a single Primo application on root and shoot growth parameters of Kentucky bluegrass over time.

Due to the difficulty in studying root systems under field conditions, we chose a water culture or hydroponic system to measure root growth over time. Kentucky bluegrass plants, variety Moonlight, were grown from seed in the greenhouse and transferred six weeks after germination into the hydroponic system. Individual plants were used in the hydroponic system. Irradiance levels were 800 to 900 micromoles per square meter per second (μmol m-2 s-1) during a 16-hour photoperiod.

Three weeks after plants were transplanted from soil to hydroponics, half of the plants from each container were treated with a single Primo application at the label rate 0.27 kilograms (kg) actual ingredient per hectare, while untreated plants in each container served as controls. For seven weeks following Primo application, one Primo-treated and one untreated plant from each container were harvested weekly.

Shoot height, tiller number and plant color were recorded. Roots were excised as close to the crown as possible and stored at 4 degrees Celsius (C) until image analysis.

Excised roots were analyzed using the WinRhizo system (Regent Instruments Inc., Version 5.0A, Quebec, Canada). The WinRhizo system is an image-analysis system used to

Continued on page 58

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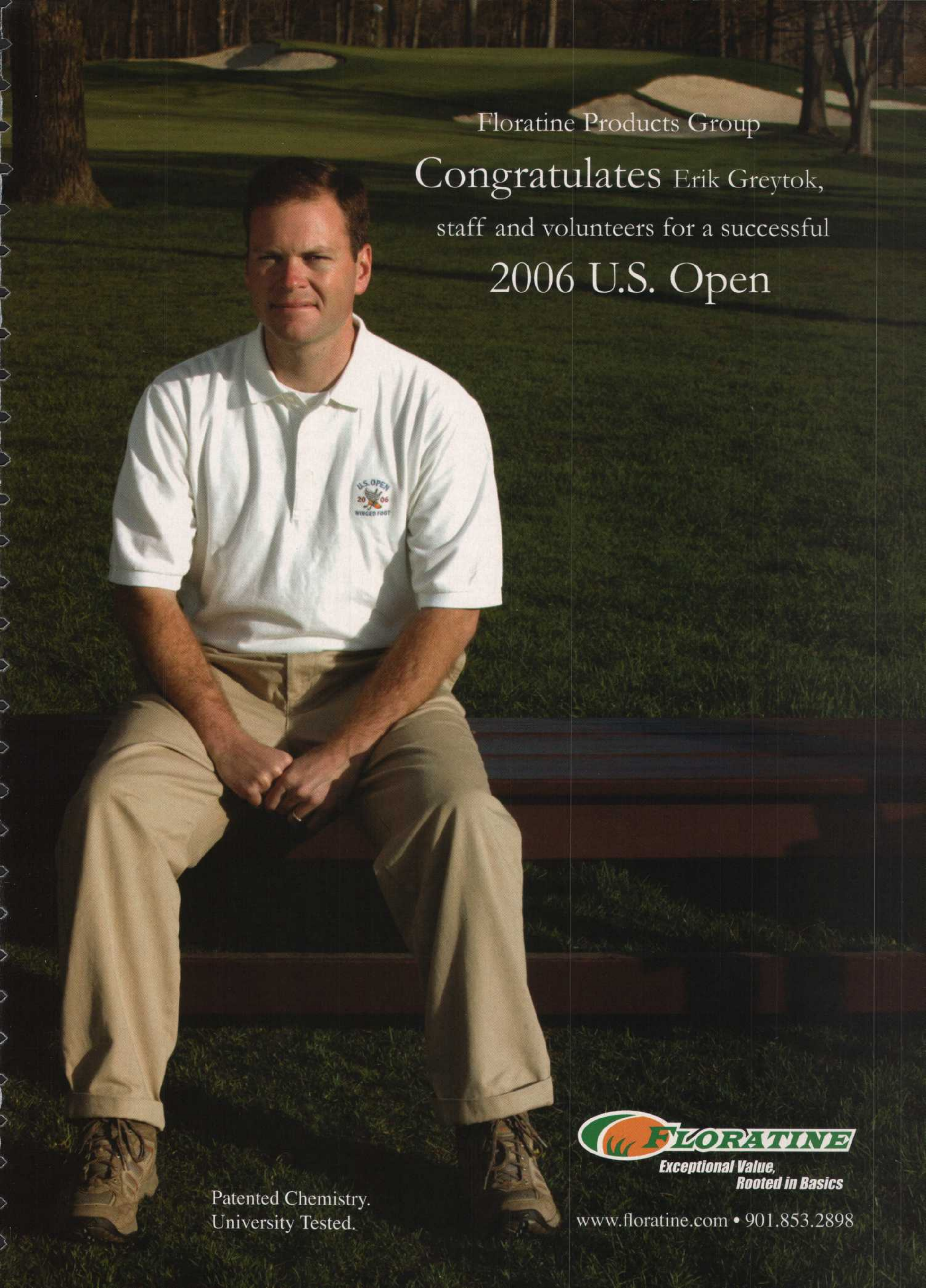
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measure root parameters, including total root length (TRL in cm), root diameter (mm) and root surface area (SA in square centimeters).

On a single plant basis, Primo-treated KBG increased tillering while plant height followed a typical pattern of inhibition and rebound reported in many Primo-treated turfgrass studies (Ervin and Koski, 2001; Fagerness et al., 2002). Root and shoot growth of Primo-treated plants had similar growth patterns: an initial reduction in TRL and SA was followed by a period of increased growth.

Thereafter, root growth slowed for both Primo-treated KBG and controls. Because Primo had no effect on average root diameter, increases in TRL and SA are because of existing vertical growth and/or root initiation.

From this study, root growth (TRL and SA) on a single-plant basis could indicate an increase in rooting for Primo-treated plants. However, because tillers are considered individual plants with individual root systems, it is important to relate root growth to changes in shoot growth. As a result, Primo-induced tillering resulted in reduced TRL and SA per tiller or less roots per tiller.

The increase in tiller number supports past research findings and anecdotal evidence of increased sward density from Primo application. However, increased tiller numbers and reduced TRL and SA per tiller from a Primo application could limit individual tiller development through lowered nutrient and water uptake. In turn, this would create greater competition among KBG plants within the sward.

Changes in root architecture and tillering between Primo-treated and control plants may be the result of altered photosynthetic rates and/or distribution of photoassimilates. Other agronomic commodities treated with PGRs have shown decreased and/or increased photosynthetic rates as well as altered photoassimilate distribution (Huang et al., 1995; Hunter and Proctor, 1994; El-Hodairi et al., 1988).

In our research, changes in photosynthetic rates of Primo-treated KBG were only slightly reduced for a very short period of time, if at all. Rather, changes in photoassimilate distribution in KBG appear to be the major affect of Primo in altering plant growth.

Researchers and turfgrass practitioners often ask how a particular treatment affects root growth or shoot growth. This research illustrates the complexity of plant root growth research.

Both root and shoot growth should be measured in order to obtain an accurate representation of the effects of exogenously-applied PGRs. Though the methods used for this study do not represent field conditions, this research clearly shows how PGRs affect energy (photoassimilate) distribution within the plant. Further research should be conducted to determine Primo effects on turfgrass rooting under field conditions.

However, using a holistic approach provides greater insight into how PGRs affect overall plant growth. Therefore, the next time you hear claims of increased rooting concerning any product, you should ask, "How does this relate to shoot growth and overall plant growth?"

Jeffrey Beasley recently completed his Ph.D. at the University of Illinois, examining the effects of PGR activity on turfgrass growth. Dr. Bruce Branham is a professor in turfgrass science at the University of Illinois.

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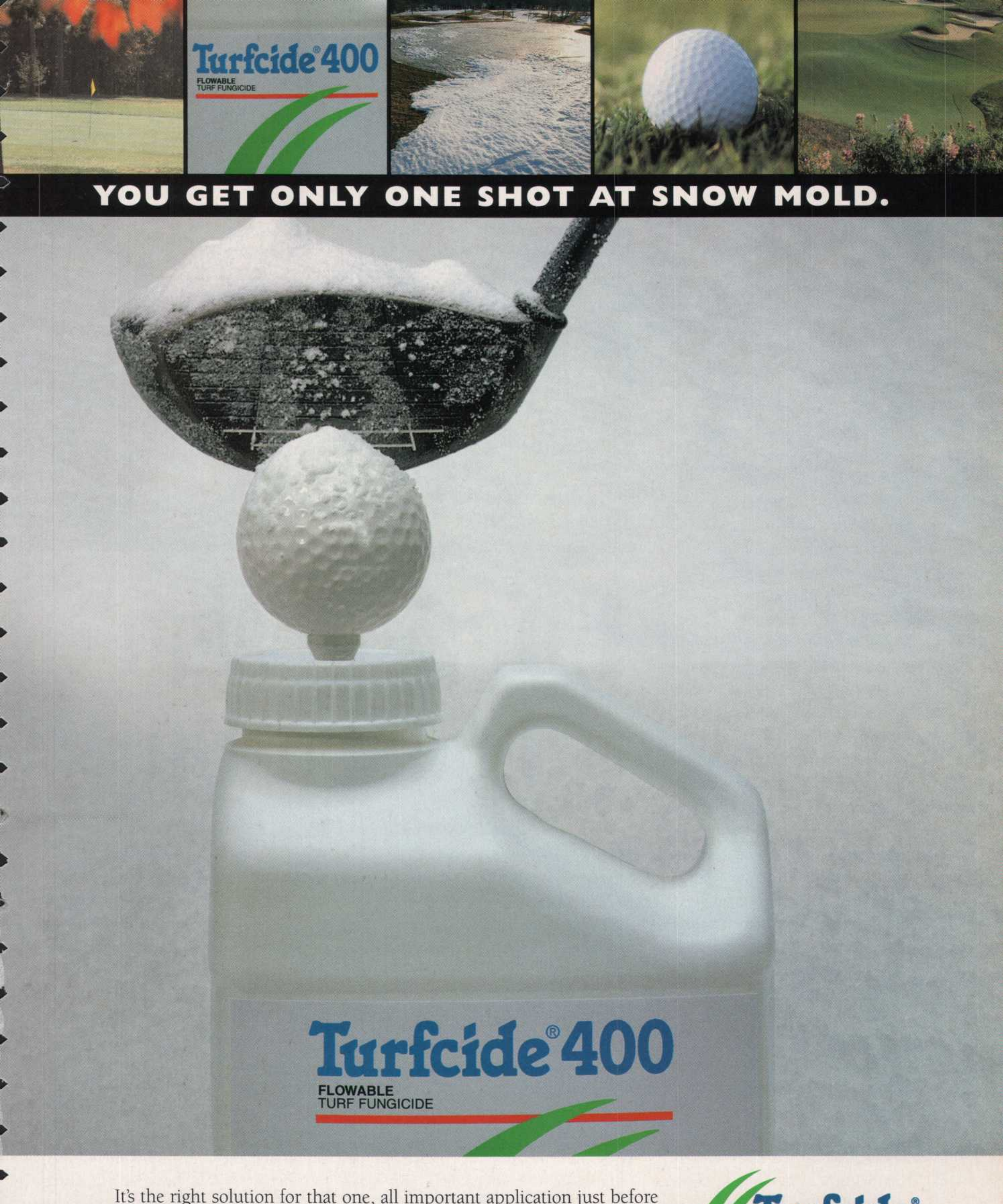

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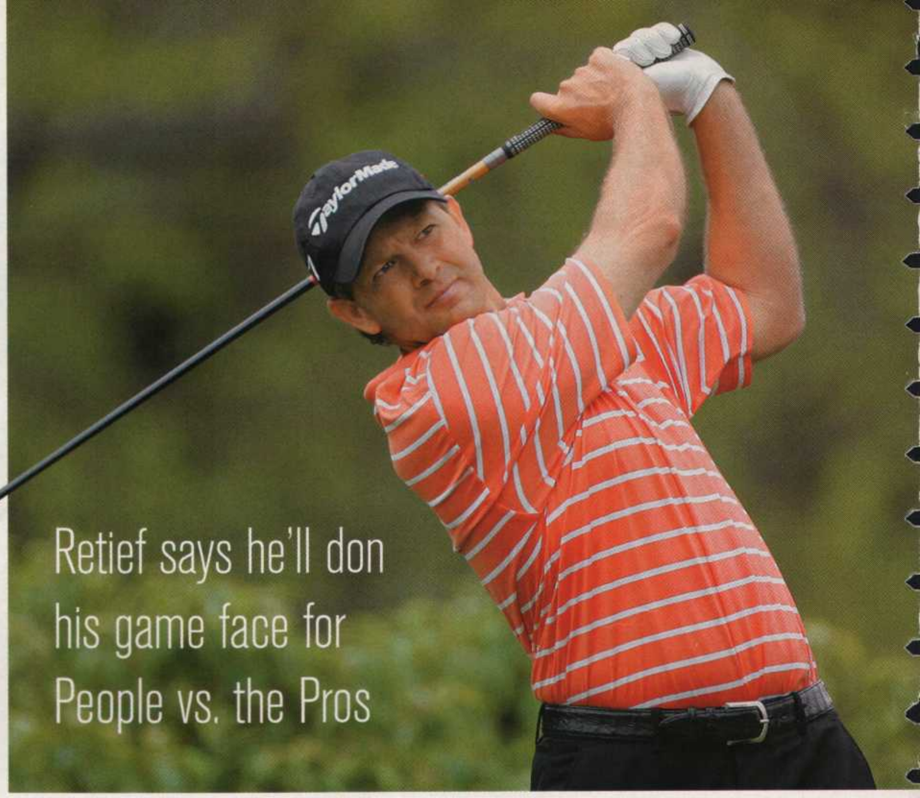

PHOTO COURTESY: PEOPLE VS. THE PROS

Retief says he'll don his game face for People vs. the Pros

Goosen Won't Loosen Up

By Larry Aylward, Editor in Chief

Retief Goosen is packing his suitcase for the BASF People vs. the Pros tournament, set for Aug. 18 through Aug. 22 at Pinehurst. He's bringing more than his lucky polo shirt and favorite golf shoes. Goosen is bringing his game face.

While the People vs. the Pros is not the pressure-packed U.S. Open, of which the 37-year-old South African has won twice, Goosen is not coming to Pinehurst to lose his match against an amateur — which could be a golf course superintendent — who he will compete against in a head-to-head 18-hole match on Pinehurst's No. 8 course for a chance to win $50,000 for a charity of choice.

Goosen, in a phone interview with *Golfdom*, says he'll be a friendly foe, but . . .

"If [the amateur] is playing well, I'll have to start pulling some tricks on him and intimidate him a little bit," Goosen says. "I'll get him extra nervous so I can try and win the dang thing."

This is the fourth year for People vs. the Pros and the second time it has been held at Pinehurst. Two hundred amateur golfers, divided into two age groups, will compete in a three-day, 54-hole handicapped stroke play tournament on Pinehurst No. 5 from Aug. 19 through Aug. 21. The low-net winner of the 18- to 49-year-old tournament will play Goosen on Pinehurst No. 8 on Aug. 22. The low-net winner of the 50-and-over tournament will play PGA pro Gary McCord for a chance at $50,000 for charity. Both matches will be broadcast on ESPN2.

Twenty-five superintendents from throughout the United States, who qualified in 20 regional qualifying tournaments hosted by BASF Professional Turf & Ornamentals, have a shot at playing Goosen or McCord. Also, the top two finishing superintendents from each age bracket (outside of the two overall winners) will square off in the third-annual BASF Superintendents' Cup Tournament, also set for Aug. 22, for the chance to win $15,000 cash and $10,000 in BASF products.

This is the third year that BASF has sponsored the event. It's the second time BASF will be the title sponsor. As title sponsor, BASF gets to place its name before the event's name, as in the "BASF People vs. the Pros." As title sponsor BASF also gets more airtime on ESPN2 for advertising.

Toni Bucci, business manager for BASF Professional Turf & Ornamentals, says BASF will take advantage of that airtime to promote superintendents. "Our strategy is to educate the public in general, particularly golfers, about the valuable work that superintendents do," she says.

Goosen, who won the U.S. Open at Southern Hills Country Club in 2001 and again at Shinnecock Golf Club in 2004, says he is looking forward to People vs. the Pros. "It's great for amateurs to be able to play against the pros," he says.

If Goosen ends up playing a superintendent in his title match, chances are he'll have some kind words to say to that person before he dons his game face.

"Without them, we wouldn't have good golf courses to play on," Goosen says of superintendents. "It's a skillful job they do. It's not just about cutting grass. You need to have a lot of knowledge about that grass. It's a very difficult job."

Goosen says he has a better understanding of what superintendents do because he has begun to design his own golf courses. He says he has talked to superintendents in-depth about several aspects associated with golf course design and

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