Effect of Demethylation Inhibiting Fungicides on 'Tifgreen' Bermudagrass Quality

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ADDITIONAL INDEX WORDS. *Cynodon* sp., golf course putting greens, plant growth regulation, sterol inhibiting fungicides

SUMMARY. Eight demethylation inhibiting (DMI) fungicides were applied at two rates to 'Tifgreen' bermudagrass [*Cynodon dactylon* (L.) Pers. x *C. transvaalensis* Burt-Davy] to determine if DMI fungicides would produce a plant growth regulation effect on healthy bermudagrass. After three applications at 28- to 30-day intervals, compared to the control, both rates of cyproconazole, bromuconazole, propiconazole and triadimefon and the high rate of myclobutanil significantly decreased turfgrass quality on at least one evaluation date in each year of the study. The low rate of myclobutanil and both rates of tebuconazole and fenbuconazole did not adversely effect turfgrass quality in either year. For both rates of fenarimol, there was only one date during both years of the study when the turfgrass quality was significantly lower than the control. These results demonstrate the wide range of physiological activity the DMI fungicides can have on bermudagrass.

Demethylation inhibiting (DMI) fungicides are commonly used in the turfgrass industry for control of a wide range of turfgrass diseases caused by

both leaf and root pathogens. However, DMI fungicides are known to have growth regulation effects on plants. Inhibition of gibberellin and plant sterol biosynthesis have been identified (Buchenauer, 1995; Fletcher and Hofstra, 1988). The first characteristic has been used to advantage in bermudagrass management with the DMI fungicide fenarimol (Rubigan) being used for control of *Poa annua* L. in bermudagrass overseeded with a cool-season turfgrass. The propiconazole (Banner) fungicide label indicates that the product should not be applied to bermudagrass golf greens in Florida when the temperatures exceed 90 °F (32.5 °C) because of its plant growth regulation effects.

During a previous study evaluating registered and experimental systemic fungicides for root rot disease management on bermudagrass putting greens, we observed that certain DMI fungicides significantly decreased turfgrass quality, when compared with the untreated turfgrass, by reducing turfgrass density and altering the normal leaf color (Elliott, 1995). This study had used 'Tifgreen' bermudagrass grown on a root-zone mix composed of 80% sand and 20% Canadian sphagnum peat with the turf mowed daily at a height of 0.19 inch (4.69 mm). The bermudagrass was also infected with *Gaeumannomyces graminis* (Sacc.) Arx & D. Olivier var. *graminis*, a root rot pathogen. These multiple stresses may have interacted with the DMI fungicides and resulted in the decreased turfgrass quality observed.

Golf course putting greens and tees are expected to be uniform in color, texture and density to provide a visually attractive and competitive playing surface for the golfing public. Maintenance practices that may adversely affect turfgrass quality must be identified. This study was initiated to evaluate the effect of DMI fungicides on healthy bermudagrass to determine if negative responses would still be observed when minimal stresses were imposed on the turfgrass.

Materials and methods

Five-year-old 'Tifgreen' bermudagrass growing on native soil (Margate fine sand) in southern Florida was used. It was maintained by mowing three times each week at a height of 0.25 inch (6.25 mm). Nitrogen applica-

tions of 18 lb/1000 ft² (8.8 kg/100 m²) per year were made using IBDU as the nitrogen source in a 16N-0P-13K fertilizer blend with potassium magnesium sulfate and micronutrients (Vigoro Industries, Winter Haven, Fla.).

An experiment was conducted in 1992 and in 1993, with the 1993 experiment conducted on a different portion of the bermudagrass area than the 1992 experiment. Each experiment was established as a randomized complete block design with four replicates of each fungicide treatment. Plots were 5 × 7 ft (1.5 × 2.1 m) in size. Fungicides were applied at 28- to 30-day intervals with applications made on 20 Apr., 20 May, and 17 June 1992 and 30 Apr., 30 May, and 29 June 1993. The fungicides were mixed with deionized water and applied at a water equivalent of 2 gal/1000 ft² (8.2 L/100 m²) using a backpack CO₂ pressurized sprayer [40 psi (276 kPa) at the handle] with stainless-steel Tee Jet nozzles 8002. Immediately after a fungicide had been applied, it was drenched into the root zone by irrigating at a rate of 1.5 gal/1000 ft² (6.1 L/100 m²) using a fine nozzle attachment to a garden hose. The control treatment turfgrass plots received only water. No additional chemical or biological pesticides were applied during the study period.

The fungicides evaluated that were registered or in the process of registration for turfgrass use in Florida were triadimefon (Bayleton 25% WP, Bayer Corp., Kansas City, Mo.), propiconazole (Banner 14.3% EC, Novartis, Greensboro, N.C.), fenarimol (Rubigan 11.6% AS, Dow AgroSciences, Indianapolis, Ind.), myclobutanil (Eagle 40% WP, Rohm and Haas Co., Philadelphia, Pa.), and cyproconazole (Sentinel 40% WG, Novartis, Greensboro, N.C.). Experimental fungicides evaluated were fenbuconazole (RH-7592 22.8% F, Rohm and Haas Co., Philadelphia, Pa.), tebuconazole (Lynx 25% DF, Bayer Corp., Kansas City, Mo.), and bromuconazole (EXP 10064C 20% SC, Rhone-Poulenc, Research Triangle Park, N.C.). Except for fenbuconazole in 1992, each material was applied at a high and low rate (Tables 1 and 2). Rates used were label rates for turfgrasses for the registered fungicides and suggested rates by the manufacturer for the experimental fungicides.

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Table 1. Bermudagrass quality observed in 1992 when demethylation inhibiting fungicides were applied^z to 'Tifgreen' bermudagrass.

Treatment	Rate		Turfgrass quality ^y			
	oz a.i./1000 ft ²	g a.i./100 m ²	14 July	23 July	27 July	3 August
Fenarimol	0.25	7.62	3.75 abc ^x	5.75 bcd	6.00 abc	7.25 abc
Fenarimol	0.50	15.24	3.50 bc	6.00 abcd	6.25 ab	7.25 abc
Propiconazole	0.28	8.39	4.00 abc	5.50 cde	6.25 ab	7.50 abc
Propiconazole	0.55	16.76	3.00 cd	4.75 ef	4.75 edf	5.50 ef
Triadimefon	0.50	15.24	3.75 abc	5.50 cde	6.50 a	7.50 abc
Triadimefon	1.00	30.48	3.50 bc	5.50 cde	5.50 bcd	6.50 cde
Cyproconazole	0.06	1.83	2.25 d	4.00 f	4.50 ef	5.75 def
Cyproconazole	0.13	4.02	3.00 cd	4.25 f	4.25 f	5.25 f
Myclobutanil	0.20	6.10	4.50 ab	6.00 abcd	6.50 a	7.75 ab
Myclobutanil	0.40	12.19	3.75 abc	5.50 cde	5.50 bcd	7.25 abc
Fenbuconazole	0.13	3.81	4.75 a	6.50 ab	6.50 a	8.00 a
Bromuconazole	0.21	6.40	3.00 cd	5.25 de	5.25 cde	6.75 b
Bromuconazole	0.42	12.81	2.25 d	4.00 f	4.00 f	4.00 g
Tebuconazole	0.25	7.62	4.00 abc	6.25 abc	6.25 ab	7.25 abc
Tebuconazole	0.50	15.24	4.50 ab	6.50 ab	6.25 ab	7.25 abc
Control			4.25 ab	6.75 a	6.50 a	8.00 a
Pr > F			0.0001	0.0001	0.0001	0.0001

^zFungicide applications were made on 20 Apr., 20 May, and 17 June 1992.

^yTurfgrass quality was based on color and density using a scale of 1 (poor quality) to 10 (best quality). Values are means of four replicate plots.

^xMeans in the same column followed by the same letter are not significantly different ($P \leq 0.05$), according to Waller-Duncan k ratio *t* test.

Quality of the turfgrass canopy was used for evaluating bermudagrass response to the fungicides. Quality values were based on overall foliar color and plant density of each plot and were determined using a linear scale of 1 to 10, where 1 was equivalent to the poorest quality (virtually 100% necrosis of leaf tissue and <50% density) and 10 the best quality (0% necrosis and chlorosis, and 100% density). Plot evaluations were initiated once differences became apparent.

Data were analyzed by analysis of variance using the GLM procedure (SAS Institute Inc., Cary, N.C.). Means were compared using the Waller-Duncan k ratio *t* test.

Results

Rainfall received in 1992 during the experimental period was the following: 3.4 inch (8.4 cm) in April, 0.9 inch (2.2 cm) in May, 23.4 inch (58.4 cm) in June, and 3.4 inch (8.4 cm) in July. Rainfall received in 1993 during the experimental period was the following: 2.0 inch (5.0 cm) in April, 0.6 inch (1.4 cm) in May, 8.3 inch (20.7 cm) in June, and 12.2 inch (30.5 cm) in July. No diseases were observed during the experimental period. Although mole crickets were present, they were randomly located throughout the bermudagrass area and so were not treated with chemicals to prevent

potential interactions with the fungicides. Weeds did become a significant problem in those plots where the turfgrass growth and subsequent density was reduced, but no herbicides were applied for their control. Dates with significant differences ($P \leq 0.05$) in turfgrass quality results are presented in Table 1 (1992) and Table 2 (1993).

From 22 to 29 June 1992, after the third fungicide application, the study area received 14 inch (35 cm) rainfall and minimal sunlight due to a tropical storm. As a result, a reduction in turfgrass density and an increase in leaf chlorosis and necrosis was observed for the entire study area. Significant differences in turfgrass quality were first observed on 14 July as the turf began to recuperate from the storm (Table 1). In 1993, significant differences in turfgrass quality were first observed on 28 June, one day prior to the third fungicide application (Table 2). Unlike 1992, the overall turfgrass quality at this time was good with dense turf and normal leaf color. No stresses had been placed on the turf by the natural environment. However, from 12 July through 23 July, 9.4 inch (23.6 cm) of rainfall was received or approximately 79% of the total rainfall for that month. Turfgrass quality declined over the entire study area beginning in mid-July.

In 1992 and 1993, both rates of

cyproconazole and bromuconazole and the high rate of propiconazole significantly reduced bermudagrass quality compared to the control on all dates evaluated. In both years, neither tebuconazole, fenbuconazole nor the low rate of myclobutanil significantly affected bermudagrass quality. For fenarimol, on only one of four dates in 1992 for the low rate and only one of three dates for the high rate in 1993 was significantly decreased bermudagrass quality observed, compared to the control. Significantly decreased bermudagrass quality was observed on one date in 1992 and two dates in 1993 for the low rate of propiconazole. On three dates in 1992 and all dates in 1993, the high rate of triadimefon resulted in significantly lower bermudagrass quality than the control. Reduced bermudagrass quality was observed on three dates in 1992 and one date in 1993 for the high rate of myclobutanil.

Discussion

All the fungicides used in this study are a subgroup of fungal sterol biosynthesis inhibitors (Kuck et al., 1995). They are referred to as demethylation inhibitors (DMIs) because they have a common site of action within the fungal sterol biosynthesis pathway. These fungicides inhibit demethylation at position 14 of lanosterol or 24-methylene dihydrolanosterol, precursors of fungal sterols. Based on their chemical deriva-

Table 2. Bermudagrass quality observed in 1993 when demethylation inhibiting fungicides were applied² to 'Tifgreen' bermudagrass.

Treatment	Rate		Turfgrass quality ³		
	oz a.i./1000 ft ²	g a.i./100 m ²	28 June	16 July	2 August
Fenarimol	0.25	7.62	7.00 a ^x	5.25 abc	4.25 a
Fenarimol	0.50	15.24	7.00 a	4.75 bcd	4.00 abc
Propiconazole	0.28	8.39	6.75 ab	4.50 cde	3.25 cde
Propiconazole	0.55	16.76	5.50 de	3.00 fgh	2.75 de
Triadimefon	0.50	15.24	6.50 abc	4.00 def	3.50 bcd
Triadimefon	1.00	30.48	6.25 bc	3.50 efg	3.50 bcd
Cyproconazole	0.06	1.83	6.00 cd	2.75 gh	2.25 e
Cyproconazole	0.13	4.02	5.25 e	2.75 gh	2.75 de
Myclobutanil	0.20	6.10	7.00 a	5.25 abc	4.25 abc
Myclobutanil	0.40	12.19	7.00 a	5.00 abcd	3.50 bcd
Fenbuconazole	0.13	3.81	7.00 a	6.00 a	4.75 a
Fenbuconazole	0.25	7.62	7.00 a	5.75 ab	4.75 a
Bromuconazole	0.21	6.40	6.25 bc	3.50 efg	2.75 de
Bromuconazole	0.42	12.81	5.25 e	2.00 h	2.25 e
Tebuconazole	0.25	7.62	7.00 a	5.50 abc	4.25 abc
Tebuconazole	0.50	15.24	7.00 a	5.75 ab	4.50 ab
Control			7.00 a	6.00 a	4.75 a
Pr > F			0.0001	0.0001	0.0001

²Fungicide applications were made on 30 Apr., 30 May, and 29 June 1993.

³Turfgrass quality was based on color and density using a scale of 1 (poor quality) to 10 (best quality). Values are means of four replicate plots.

^xMeans in the same column followed by the same letter are not significantly different ($P \leq 0.05$), according to Waller-Duncan k ratio *t* test.

tion, fenarimol is a pyrimidine fungicide; all the other fungicides used in this study are triazole or azole fungicides.

In Elliott's 1995 study, it was possible that the additional stress of disease placed on the turf may have induced the turfgrass quality decline observed in association with DMI fungicides. In the current study, attempts were made to minimize physical stresses on the 'Tifgreen' bermudagrass. The height of cut was increased and the number of mowing operations each week reduced from six to three. Fungicide application methods were the same in both studies, but the application interval was increased from 21 days to 28 d in this study to try to minimize potential fungicide effects.

Despite the reduction in physical stresses, both rates of cyproconazole, bromuconazole, propiconazole and triadimefon and the high rate of myclobutanil significantly decreased turfgrass quality compared to the control in the current study. It should be noted that lower rates of cyproconazole and bromuconazole were used in the current study than in the previous study (Elliott, 1995), and damage was still observed. Although both rates of fenarimol and the

low rate of myclobutanil had consistently poorer turfgrass quality in the disease study, that was not observed in the current study. Tebuconazole did not affect turfgrass quality adversely in the previous study (Elliott, 1995) and did not do so in the current study.

The plant growth regulation effect induced by DMI fungicides is well documented (Buchenauer, 1995; Fletcher and Hofstra, 1988), and plant growth regulating compounds that belong to the triazole chemical class are available commercially. Initially, clipping weights were to be measured to help document growth regulation. However, this was abandoned since weeds replaced the turf and actually increased the clipping weights (unpublished data). The primary weed was prostrate spurge [*Chamaesyce maculata* (L.) Small]. It did not appear to be affected by the DMI fungicides. These results demonstrate the wide range of plant activity the DMI fungicides can have on bermudagrass. Although many of these fungicides are currently registered for use on bermudagrass for disease control, some should be used with caution, especially if the turfgrass is stressed.

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