Effect of Systemic Fungicides on a Bermudagrass Putting Green Infested with *Gaeumannomyces graminis* var. *graminis*

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ABSTRACT

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During a 3-year period, the systemic fungicides fenarimol, myclobutanil, propiconazole, tebuconazole, thiophanate methyl, and triadimefon were evaluated for efficacy in reversing or preventing the quality decline of a hybrid bermudagrass putting green infested with *Gaeumannomyces graminis* var. *graminis*. None of the fungicides increased turfgrass quality over that of the untreated turfgrass, whether used curatively at the highest recommended rates or preventatively at a reduced rate. However, a significant decline in turfgrass quality, when compared with the untreated turfgrass, was often associated with repeated use of the DMI fungicides fenarimol, myclobutanil, propiconazole, and triadimefon but not with the use of the DMI fungicide tebuconazole or with the benzimidazole fungicide thiophanate methyl.

Golf course putting greens are expected to be uniform in color, texture, and density in order to provide a visually attractive and competitive playing surface for the golfing public. Bermudagrass decline, caused by the fungus *Gaeumannomyces graminis* (Sacc.) Arx & D. Olivier var. *graminis*, is a root rot disease of hybrid bermudagrass (*Cyondon dactylon* (L.) Pers. × *C. transvaalensis* Burtt-Davy) maintained as putting greens in Florida (6). The disease was given the name bermudagrass decline in the early 1980s by golf course superintendents because the pathogen was unknown at that time, and this name described the general symptoms observed. *Gaeumannomyces graminis* colonizes roots, invades the root vascular system, and thus debilitates the plant due to lack of water and carbohydrate movement between roots and leaves (11). In combination with other stresses (e.g., low mowing height, nutritional deficiencies, or nutrient imbalances), advanced root disease may affect the turfgrass plants above ground, resulting in extensive foliar chlorosis and necrosis that reduces the overall quality of a putting green. These aboveground symptoms and resulting turfgrass quality decline will normally develop from July through September, a period of high rainfall in southern Florida.

Advanced symptoms of bermudagrass decline are usually apparent before the recommended treatments are initiated, since it is difficult to detect the early stages of this disease (i.e., root infection and root decline below ground), or because the symptoms are confused with Pythium root rot or nematode damage. When the current study was initiated, cultural disease control recommendations for bermudagrass decline included increasing the mowing height, increasing fertility using acidifying fertilizers, aerification, and topdressing with the appropriate root-zone medium (9). Increasing the mowing height is an effective cultural control (7), but one that is not currently acceptable to the golfing public because it reduces putting speed.

Diseases similar to bermudagrass decline include summer patch, take-all patch, necrotic ring spot, and spring dead spot (2,12). Take-all patch is caused by *G. g.* var. *avenae* (E. M. Turner) Dennis, and *G. g.* var. *graminis* is one of the fungi associated with spring dead spot. Systemic fungicides in the benzimidazole and demethylation inhibitor (DMI) chemical classes have demonstrated a limited efficacy in controlling these turfgrass root rot diseases (5). No research, however, had been conducted to validate the use of these fungicides as preventative or curative treatments for control of bermudagrass decline.

In early 1990, a putting green composed of an 80% sand and 20% Canadian sphagnum peat moss root-zone medium was constructed at the Fort Lauderdale Research and Education Center. One portion was planted in August 1990 with vegetative sprigs of hybrid bermudagrass cv. Tifgreen that were naturally infested with *G. g.* var. *graminis* (8). Small patches (<15 cm diameter) of bermudagrass decline were first observed 1 year later (August 1991). Within 1 month, extensive foliar chlorosis and necrosis was evenly distributed across the entire area resulting in a severe decline in turfgrass quality. Plants had short, black, rotted roots from which *G. g.* var. *graminis* was isolated and identified.

Using this naturally infested area, a study was initiated in September 1991 to evaluate the use of systemic fungicides to reverse the severe decline in turfgrass quality observed. Experiments were conducted on the same area in 1992 and 1993 to determine if these fungicides could prevent development of the root rot disease and subsequent decline in turfgrass quality. An in vitro evaluation of *G. g.* var. *graminis* response to the fungicides was also conducted.

MATERIALS AND METHODS

In vitro fungicide assays. Three *G. g.* var. *graminis* isolates (FL-19, FL-46, and FL-90), all obtained from symptomatic bermudagrass in Florida, were used for this study. Isolates were stored on potato-dextrose agar (PDA, Difco Laboratories, Inc., Detroit, Mich.) slants at 2 to 4°C and as colonized agar plugs in glycerol at –70°C.

The fungicides evaluated were triadimefon (Bayleton 25% WP), propiconazole (Banner 14.3% EC), fenarimol (Rubigan 11.6% AS), tebuconazole (Lynx 25% DF), myclobutanil (Eagle 40% WP) and thiophanate methyl (Fungo 85% DF) (Table 1). All compounds were added at 1, 10, and 100 µg a.i. ml^{-1} to autoclaved and cooled PDA. The check treatment was unamended PDA. Media plates were inoculated by placing one 5-mm-diameter agar plug of the test isolate in the center of a 9-cm-diameter petri plate. There were three plates per treatment for each isolate. Radial growth of the colonies was determined after 5 and 10 days incubation at 28°C. Percent radial growth of an isolate on amended PDA compared with unamended PDA was calculated. All compounds were evaluated twice.

1991 putting green experiments. The bermudagrass putting green used in 1991 had been maintained as a typical putting green with a mowing height of 4.69 mm (cut 5 or 6 times each week) and nitrogen applications of 781 kg ha^{-1} per year using IBDU as the nitrogen source in a 1N:0P:0.83K fertilizer blend with potassium magnesium sulfate and micronutrients (Vigoro Industries, Winter Haven, Fla.). The soil pH was 7.3. After the turfgrass quality had severely declined due to advanced root disease, two experiments were initiated to evaluate the turfgrass response to systemic fungicides, one with and one

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without the use of recommended cultural control practices for bermudagrass decline.

Each experiment was established as a randomized complete block design with five replicates of each treatment. Plots were 3.25 m^2 in size. Fungicides were applied at curative rates (Tables 2 and 3) at 21-day intervals with applications made on 21 September, 11 October, and 4 November 1991. Fungicides were mixed with deionized water and applied at a water equivalent of 815 liters/ha^{-1} using a backpack CO_2-pressurized sprayer (28 kg/m^{-2} pressure at the handle) with stainless steel 8002 Tee Jet nozzles. Immediately after a fungicide had been applied, it was drenched into the root zone by irrigating at a rate of 18,400 liters/ha^{-1} using a fine-nozzle attachment to a garden hose. The check treatment turfgrass plots received only water. No additional chemical or biological pesticides were applied during the study period.

For one experiment, no cultural practices were initiated, only the fungicides were applied. The fungicides evaluated in this field experiment were triadimefon (25% WP), propiconazole (14.3% EC), fenarimol (11.6% AS), tebuconazole (25% DF), myclobutanil (40% WP), bromuconazole (20% SC), hexaconazole (10% SC), cyproconazole (40% WG), and thiophanate methyl (85% DF). It was evident by 18 October that the fungicides were not aiding in the recovery of the turfgrass. Therefore, the mowing height in this experiment was increased from 4.69 mm to 6.25 mm on 20 October.

For the second experiment, due to limited space, only the currently registered fungicides, triadimefon, propiconazole, fenarimol, and thiophanate methyl, were applied. In contrast to the first experiment, cultural practices were initiated on all plots in the second experiment just prior to the first fungicide application. These practices included increasing the mowing height to 6.25 mm. The area was core aerified (9.5 mm diameter and 6 cm deep), cores were removed, and the area topdressed with the same root-zone medium used to build the putting green. This area was also provided with additional nutrients twice each month until January 1992 using 24 kg/ha^{-1} of a 1N:1P:1K fertilizer blend composed of ammonium sulfate, triple super phosphate, potassium magnesium sulfate, iron oxide, and a micronutrient source containing manganese, copper, zinc, and boron. The mowing height was decreased for all plots in both experiments to the original long-term height of 4.69 mm in January 1992.

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 = the poorest quality (virtually 100% necrosis of leaf tissue, and <50% density) and 10 = the best quality (0% necrosis and chlorosis, and 100% density). Plots were evaluated every month or as differences became apparent. Random plant samples were obtained to confirm the presence of *G. g.* var. *graminis*, primarily by observing presence of lobed hyphopodia characteristic of this fungus.

1992 and 1993 putting green experiments. These experiments were conducted to examine fungicide use on a preventative treatment schedule for controlling bermudagrass decline. The experiments were established on the same Tifgreen bermudagrass area used in 1991. Plots treated in 1991 with bromuconazole, cyproconazole, and hexaconazole were not used in the 1992 experiment as these plots had not recovered from these fungicide treatments. These plots were acceptable for use in 1993.

In both years, the bermudagrass height was maintained at 4.69 mm, and nitrogen fertility was 781 kg/ha^{-1} per year. Each experiment was established as a randomized complete block design with four replicates of each treatment. Plots were 3.25 m^2 in size. Fungicides evaluated were triadimefon, propiconazole, fenarimol, tebuconazole, myclobutanil, and thiophanate methyl. Reduced fungicide rates were used, and the spray interval was extended to 28 to 30 days (Tables 4 and 5). The same spray equipment and application methods used in 1991 were used in both years. No synthetic pesticides were applied during the study periods. *Bacillus thuringiensis* var. *kurstaki* endotoxin (DiPel, Abbott Labs, North Chicago, Ill.) was used according to label recommendations to control tropical sod webworms (*Herpetogramma phaeopteralis*). No other diseases were observed, but blue-green algae (cyanobacteria) did develop in areas with exposed soil due to decreased turfgrass density. Plants exhibiting symptoms were collected to confirm presence of *G. g.* var. *graminis* on the roots.

The 1992 experiment consisted of the six fungicide treatments and a check treatment (Table 4). Each fungicide was applied on 1 May, 29 May, and 1 July. In

Table 1. Inhibition of radial growth of *Gaeumannomyces graminis* var. *graminis* isolates by six systemic fungicides incorporated into potato-dextrose agar (PDA)

	Percent radial growth[y]			
	1 μg a.i. ml^{-1}		10 μg a.i. ml^{-1}	
Fungicide	**Mean[z]**	**SD**	**Mean**	**SD**
Fenarimol (11.6% AS)	5	2	0	–
Myclobutanil (40% WP)	4	2	0	–
Propiconazole (14.3% EC)	3	2	0	–
Tebuconazole (25% DF)	9	4	0	–
Thiophanate methyl (85% DF)	99	4	8	4
Triadimefon (25% WP)	66	28	7	3

[y] Percent radial growth was calculated after 5 days growth at 28°C by dividing radial growth of isolate on fungicide-amended PDA by radial growth of isolate on unamended PDA.
[z] Means and standard deviations (SD) were calculated from data pooled for three isolates over two experiments (18 replicates per treatment).

Table 2. Putting green turfgrass quality observed in 1991 associated with curative fungicide treatments applied for the control of bermudagrass decline

		Turfgrass quality[z]					
Fungicide	**Rate[y] (kg a.i. ha^{-1})**	**20 September**	**18 October**	**30 October**	**18 November**	**5 December**	**23 December**
Fenarimol (11.6% AS)	1.42	2.8 a	2.0 a	2.0 c	5.2 b	5.8 c	5.0 c
Myclobutanil (40% WP)	1.22	2.6 a	2.0 a	2.4 bc	4.6 b	5.8 c	5.0 c
Triadimefon (25% WP)	3.05	2.8 a	2.0 a	1.8 c	4.6 b	5.6 c	4.8 c
Bromuconazole (20% SC)	1.83	2.4 a	2.0 a	1.0 d	2.0 e	3.4 e	2.6 f
Cyproconazole (40% WG)	0.40	2.8 a	2.2 a	2.0 bc	3.0 d	4.0 de	3.4 de
Hexaconazole (10% SC)	0.61	2.8 a	2.2 a	1.8 bc	3.8 c	4.4 d	3.8 d
Propiconazole (14.3% EC)	1.75	2.8 a	2.0 a	1.6 c	2.6 e	4.0 d	3.2 d
Tebuconazole (25% DF)	1.53	2.6 a	2.2 a	3.8 a	6.8 a	8.4 a	7.8 a
Thiophanate methyl (85% DF)	11.67	2.8 a	2.0 a	3.4 a	7.0 a	7.0 b	6.0 b
Check	. . .	2.6 a	2.2 a	3.2 ab	6.8 a	7.0 b	6.0 b

[y] Fungicides were applied 21 September, 11 October, and 4 November 1991. Mowing height was increased from 4.69 mm to 6.25 mm on 20 October.
[z] Turfgrass quality was based on color and density using a scale of 1 (poor quality) to 10 (best quality). Values are means of five replicate plots. Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$), according to the Waller Duncan k-ratio t test.

1993, there were twelve fungicide treatments and a check treatment (Table 5). Each of the six fungicides was applied for a total of three and five applications per fungicide. Plots receiving three and five fungicide applications were sprayed on 1 May, 31 May, and 30 June. Plots receiving five applications were also sprayed on 7 August and 6 September. In 1993, due to the severity of the decline in turfgrass quality, the cutting height was increased to 6.25 mm in early August. Visual quality of plots was evaluated, as described previously, as quality differences became apparent.

RESULTS

In vitro fungicide assay. Growth on PDA for all three *G. g.* var. *graminis* isolates was completely inhibited by 100 μg a.i. ml^{-1} of each of the six fungicides evaluated and by 10 μg a.i. ml^{-1} of fenarimol, myclobutanil, propiconazole, and tebuconazole. There was greater than 80% reduction in radial growth, when compared with the unamended PDA controls, for all three isolates at 10 μg a.i. ml^{-1} of triadimefon and thiophanate methyl and at 1 μg a.i. ml^{-1} of fenarimol, myclobutanil, propiconazole, and tebuconazole (Table 1).

1991 putting green experiments. These experiments utilized fungicides as curative treatments, after the bermudagrass had severely declined in quality. From July through September, the turf received a total of 71.6 cm of precipitation (23.8 cm in July, 28.4 cm in August, 19.4 cm in September). For the experiment in which only the fungicides were used as initial treatments, turfgrass quality did not improve until after the mowing height was increased on 20 October (Table 2). None of the fungicide treatments resulted in turfgrass quality better than that of the untreated turfgrass until December, when the turf grass treated with tebuconazole had significantly better quality. Turfgrass treated with fenarimol, myclobutanil, triadimefon, bromuconazole, cyproconazole, hexaconazole, and propiconazole had significantly lower quality than the untreated turfgrass in November and December, after all three fungicide applications had been made.

At that time, the fungicides could be divided, based on their effect on turfgrass quality, into three groups. Tebuconazole and thiophanate methyl fungicide treatments resulted in turfgrass with quality equivalent to or better than turfgrass receiving no fungicide treatments. Fenarimol, myclobutanil, and triadimefon fungicide treatments resulted in turfgrass quality that was not statistically different from each other. The turfgrass quality of these treatment plots was not significantly greater than that of the untreated turfgrass but was significantly greater than that of the turfgrass treated with cyproconazole, hexaconazole, bromuconazole, and propiconazole. These four fungicides formed the third group of fungicides, which distinctly inhibited turfgrass growth and recovery.

Results from the second 1991 experiment, which combined fungicide treatments with cultural control practices, are presented in Table 3. None of the fungicide treatments resulted in turfgrass quality better than that of the untreated turfgrass throughout the experimental period. Turfgrass treated with propiconazole had significantly lower turfgrass quality than that treated with the other treatments on 18 October, after only two applications. After three fungicide applications, the untreated turfgrass had significantly better quality than the turfgrass treated with fenarimol, propiconazole, and triadimefon. November quality scores were not obtained due to boron phytotoxicity. The large boron fertilizer particles in the micronutrient fertilizer source resulted in numerous necrotic patches (5 to 8 cm diameter) across all treatments that interfered with turfgrass quality evaluation.

1992 and 1993 putting green experiments. The use of fungicides to prevent bermudagrass decline was evaluated in 1992 and 1993. Bromuconazole, hexaconazole, and cyproconazole fungicides were deleted from these experiments and reduced fungicide rates were used for the remaining six fungicides. The 1991 plots that had been treated with bromuconazole, hexaconazole, and cyproconazole were not used in the 1992 study as the bermudagrass in these plots still had not recovered sufficiently from the negative growth-regulating effect of these fungicide treatments. The turfgrass in these plots had regained the normal green color, but stolon and rhizome extension was reduced substantially, which resulted in thin turf. The remaining turfgrass plots appeared to have normal growth and were utilized as the experimental site.

In 1992, turfgrass quality differences were observed on 17 June but were not statistically significant and were not due to the development of root disease symptoms (Table 4). No differences were observed again until 27 August when a significant decline in turfgrass quality, compared with that of the untreated turfgrass, was observed for turf that had been treated with propiconazole. Again, quality differences were not due to root disease symptoms. Foliar symptoms of bermudagrass decline were not observed until late September, probably due to the relatively dry summer. The turf received only 39.5 cm of precipitation from July through September (8.3 cm in July, 13.7 cm in August, 17.5 cm in September). In late September, and in October, none of the fungicide treatments resulted in significantly better turfgrass quality than that of untreated turfgrass. Lobed hyphopodia of *G. g.* var. *graminis* were observed on plants with disease

Table 3. Putting green turfgrass quality observed in 1991 associated with curative fungicide treatments combined with cultural practices for the control of bermudagrass decline

Fungicide	Rate[y] (kg a.i. ha^{-1})	Turfgrass quality[z] 20 Sept.	18 Oct.	5 Dec.	23 Dec.
Fenarimol (11.6% AS)	1.42	3.2 a	4.0 a	6.0 b	5.9 b
Propiconazole (14.3% EC)	1.75	3.0 a	3.0 b	4.8 c	5.4 bc
Triadimefon (25% WP)	3.05	2.8 a	4.0 a	5.0 c	5.3 c
Thiophanate methyl (85% DF)	11.67	2.6 a	4.0 a	6.6 ab	6.8 a
Check	...	2.8 a	4.0 a	6.8 a	6.8 a

[y] Fungicides were applied 21 September, 11 October, and 4 November 1991. For the duration of the study, the mowing height was increased from 4.69 mm to 6.25 mm. Other cultural control practices initiated are described in the text.

[z] Turfgrass quality was based on color and density using a scale of 1 (poor quality) to 10 (best quality). Values are means of five replicate plots. Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$), according to the Waller Duncan k-ratio t test.

Table 4. Putting green turfgrass quality observed in 1992 associated with preventative fungicide treatments applied for the control of bermudagrass decline

Fungicide	Rate[x] (kg a.i. ha^{-1})	Turfgrass qualit[y,z] 17 June	27 Aug.	30 Sept.	22 Oct.
Fenarimol (11.6% AS)	0.71	7.5 a	6.5 bc	4.8 a	5.5 a
Myclobutanil (40% WP)	0.73	7.1 a	6.3 bc	4.5 a	5.6 a
Propiconazole (14.3% EC)	0.87	7.3 a	5.5 c	4.8 a	5.8 a
Tebuconazole (25% DF)	0.76	6.9 a	7.8 a	4.8 a	5.8 a
Triadimefon (25% WP)	1.53	7.4 a	7.0 ab	4.8 a	5.5 a
Thiophanate methyl (85% DF)	5.84	6.4 a	6.0 bc	4.5 a	5.5 a
Check	...	6.8 a	6.7 ab	3.7 a	4.5 a

[x] Fungicides were applied 1 May, 29 May, and 1 July 1992.

[y] Turfgrass 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. Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$), according to the Waller Duncan k-ratio t test.

[z] Foliar symptoms of bermudagrass decline were not observed until late September.

symptoms, and the fungus was isolated and identified from rotted roots.

In 1993, the turf received 62.7 cm of precipitation from July through September (30.0 cm in July, 14.9 cm in August and 17.8 cm in September). After two and three fungicide applications, turfgrass treated with fenarimol, myclobutanil, propiconazole, and triadimefon exhibited significantly lower quality than did untreated turfgrass (Table 5). These quality differences were apparent even before foliar disease symptoms were observed in mid-July. No fungicide treatment had significantly better quality than untreated turfgrass except on July 15. On that date, plots treated with thiophanate methyl had significantly better turfgrass quality. By increasing the cutting height beginning 1 August, turfgrass quality improved overall by 13 August, except for the turfgrass treated with propiconazole, which had significantly lower quality values than all other treatments on that date. Lobed hyphopodia of *G. g.* var. *graminis* were observed on plants with disease symptoms, and the fungus was isolated and identified from rotted roots.

Turfgrass treated with four and five applications of propiconazole, fenarimol, and triadimefon had significantly lower quality than turfgrass treated with only three applications of these fungicides, and had significantly lower quality than untreated turfgrass with the exception of triadimefon on 5 October. Turfgrass treated with only three applications of fenarimol and triadimefon, but not propiconazole, did recover sufficiently to have quality values that were not significantly different from the untreated turfgrass by 13 August.

DISCUSSION

When this study was initiated in 1991, thiophanate methyl, triadimefon, propiconazole, and fenarimol were registered for use on bermudagrass golf course putting greens. The remaining fungicides were experimental fungicides that were expected to be registered for golf courses in the future. All the fungicides are systemic fungicides that are translocated primarily in the xylem. Thiophanate methyl is a benzimidazole fungicide that inhibits fungal microtubule formation (3), whereas the remaining fungicides inhibit demethylation of fungal ergosterol precursors and are classified as demethylation inhibitors or DMIs (1). Benomyl, another benzimidazole fungicide, was not included in the study since it was apparent that it would not be available for turfgrass use in Florida in the near future. All fungicides were applied using the same application method for two reasons. First, the fenarimol label states that the turfgrass should be thoroughly irrigated after product application. Second, previous work with summer patch disease, a root disease similar to bermudagrass decline, indicated benzimidazole fungicide applications in larger water amounts improved fungicide efficacy (5).

To obtain the actual bermudagrass root response to the fungicides would have required destructive sampling of the plots. Therefore, quality of the turfgrass canopy was used for evaluating bermudagrass response to the fungicides. Since it is the aboveground turfgrass quality that is the primary concern of the golf course superintendent, this type of evaluation is reflective of the industry's method of evaluating fungicide efficacy. Root samples were obtained to confirm the presence or absence of root rot symptoms when turfgrass quality declined. Association of *G. g.* var. *graminis* with root symptoms was determined at that time.

Over the 3-year study period, none of the fungicides evaluated, whether used curatively or preventatively, provided long-term significant improvement in turfgrass quality over the untreated bermudagrass. In fact, a negative effect on turfgrass quality was often observed with some of the DMI fungicides. The plant growth regulation effect induced by DMI fungicides, including turfgrasses, is well documented (1,10), and plant growth regulating compounds that belong to this chemical class are available commercially. These compounds bind to cytochrome P-450, which inhibits gibberellin and sterol biosynthesis in plants as well as fungi. Benzimidazole fungicides have cytokinin-like properties but are not considered to have deleterious effects on plants, even at relatively high doses (4).

The negative effect of propiconazole on bermudagrass recovery from the root rot disease in 1991 and on healthy bermudagrass in 1992 and 1993 was not unexpected. The propiconazole label states that "in FL, do not apply Banner [propiconazole] to Bermudagrass golf course greens when temperatures exceed 90^{O}F [32.5 C]." Daily high temperatures were in this range when propiconazole was applied in 1991. However, this temperature was not reached until 11 June in 1992 and 28 June in 1993, after propiconazole had been applied twice. Many golf course superintendents have interpreted this statement to mean that propiconazole should not be applied when the application temperature is above 32.5°C. Based on the observations in this study, a more accurate interpretation would be to not apply this product if temperatures are expected in this range within 30 days of the application, especially if the product has been applied in the previous month(s).

A consistent decline in turfgrass quality was also observed for triadimefon and fenarimol, and, to a lesser extent, for my-

Table 5. Putting green turfgrass quality observed in 1993 associated with preventative fungicide treatments applied for the control of bermudagrass decline

Fungicide	Rate[w] (kg a.i. ha^{-1})	Turfgrass quality[x,y] 29 June	15 July	27 July	13 August	27 August	13 September	5 October
Fenarimol (11.6% AS) (3)[z]	0.71	6.3 c	4.6 c	3.8 ab	5.0 a	6.3 abc	6.6 ab	5.8 ab
Fenarimol (5)					5.0 a	5.3 d	5.8 de	5.0 de
Myclobutanil (40% WP) (3)	0.73	6.4 bc	3.9 d	3.1 bc	5.0 a	6.8 a	7.0 a	5.6 abc
Myclobutanil (5)					5.0 a	5.5 cd	6.5 ab	5.4 bcd
Propiconazole (14.3% EC) (3)	0.87	5.4 d	3.3 e	2.6 c	4.0 b	5.8 bcd	6.4 bc	5.5 abc
Propiconazole (5)					3.0 c	4.3 e	5.3 e	4.5 e
Tebuconazole (25% DF) (3)	0.76	7.0 a	4.9 bc	4.4 a	5.0 a	6.8 a	7.0 a	6.0 a
Tebuconazole (5)					5.0 a	6.5 ab	6.8 ab	6.0 a
Triadimefon (25% WP) (3)	1.53	6.0 c	4.1 d	3.3 bc	5.0 a	6.8 a	7.0 a	6.0 a
Triadimefon (5)					5.0 a	5.3 d	5.9 cd	5.3 bcd
Thiophanate methyl (85% DF) (3)	5.84	6.9 ab	5.9 a	4.5 a	5.0 a	5.3 d	6.6 ab	5.5 abc
Thiophanate Methyl (5)					5.0 a	5.3 d	6.9 ab	5.1 cd
Check	. . .	7.0 a	5.3 b	4.3 a	5.0 a	6.3 abc	7.0 a	5.6 abc

[w] All fungicides treatments were applied on 1 May, 31 May, and 30 June 1993. Two additional applications were made on 7 August and 6 September for indicated treatments. Cutting height was increased 1 August from 4.69 mm to 6.25 mm.

[x] Turfgrass quality was based on color and density using a scale of 1 (poor quality) to 10 (best quality). Values on 29 June, 15 July, and 27 July for fungicide treatments are means of eight replicate plots, and check values are means of four replicate plots. All values for 13 August through 15 October are means of four replicate plots. Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$), according to the Waller Duncan *k*-ratio *t* test.

[y] Foliar symptoms of bermudagrass decline were not observed until mid-July.

[z] Number of fungicide applications.

clobutanil. Although more apparent in the 1991 curative experiments, this decline in quality was also observed when these products were used preventatively in 1992 and 1993 at reduced rates. Triadimefon and fenarimol do not have a warning statement similar to propiconazole on their labels. In fact, fenarimol is used in Florida as a herbicide prior to overseeding putting greens with cool-season turfgrasses to control *Poa annua*. The recommended treatment in southern Florida for this purpose is three applications of fenarimol at 1.42 kg/ha^{-1} every 10 to 14 days beginning in late September and early October, depending on when overseeding will begin. This is the rate evaluated in the curative disease control experiments in 1991 that appeared to be detrimental to bermudagrass quality.

Cyproconazole, hexaconazole, and bromuconazole were detrimental to turfgrass quality at the rates evaluated in 1991, but, unlike the other DMI fungicides, the negative growth effect was observed for over 9 months. Tebuconazole always had quality ratings equivalent to or, in 1 month, significantly better than the untreated turfgrass over the 3-year study period. No negative effects were observed for tebuconazole. These results demonstrate the wide range of activity the DMI fungicides can have in affecting bermudagrass growth. Considering that some of these products are widely used on cool-season turfgrasses, it would also demonstrate the differences in plant activity between turfgrass species.

Due to the growth regulation effect of some of the DMI fungicides, it was difficult to assess disease control of the products. The three *G. g.* var. *graminis* isolates were sensitive to the six fungicides evaluated in vitro. However, since optimum turfgrass quality is the primary goal of the golf course superintendent, a fungicide that inhibits the fungus but damages the turfgrass has no actual benefit. For those fungicides that did not have a negative effect on turfgrass quality, there may still be no advantage to using these products on bermudagrass infested with *G. g.* var. *graminis*. Further evaluations would be required to determine if a consistent response could be obtained with their use. Studies with similar turfgrass patch diseases have demonstrated that an integrated approach, using chemical and cultural controls, is required for long-term disease management (5).

DMI fungicides should be used with caution on bermudagrass putting greens in Florida until more information can be obtained concerning their plant growth effects on bermudagrass. This information is needed for healthy bermudagrass and for bermudagrass that is under stress due to low mowing heights or damaged root systems from diseases or nematodes. Preliminary experiments indicate that the DMI fungicides can have a negative impact on turfgrass quality of healthy bermudagrass (M. L. Elliott, *unpublished data*). Again, this is not surprising if one considers the warning on the propiconazole label for Florida. Interactions between DMI fungicides, plant-growth regulators, and herbicides that inhibit new root growth must also be examined for their effect on bermudagrass.

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