Variation Among Creeping Bentgrass Cultivars in Recovery from Epidemics of Dollar Spot

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ABSTRACT

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Dollar spot was allowed to develop from natural inoculum in 15 cultivars of creeping bentgrass (*Agrostis palustris*) until epidemics were well established. At that time, initial disease intensities were assessed, and one-half of each plot was treated with cyproconazole at 0.3 kg a.i./ha. For each cultivar, disease intensities were assessed 6 to 14 days after treatment in both treated and untreated subplots. Three general patterns of recovery were observed: (i) significant recovery only with fungicide treatment; (ii) some recovery without treatment but greater recovery with treatment; and (iii) equal recovery with or without treatment. Only one cultivar exhibited the same recovery pattern in all 3 years; 10 of 15 cultivars exhibited the same pattern in 2 years of testing. In 1991 and 1993, nearly all cultivars tested recovered more quickly when treated with cyproconazole than when left untreated. In contrast, nearly half of the cultivars in 1992 exhibited the same level of recovery in both treated and untreated subplots. Weather conditions during the 1992 test period were cooler and wetter than during the other years of the study, which probably favored host growth and turfgrass recovery. While some cultivars exhibited partial resistance to dollar spot, no consistent association was found among creeping bentgrass cultivars between the level of partial resistance to, and recuperative ability from, dollar spot. Although the recuperative potential of cultivars varies in different environments, the ability to recover quickly from a disease outbreak could be a valuable cultivar attribute, particularly if it can sometimes occur without a curative fungicide application.

Additional keyword: *Agrostis stolonifera*

Research data exist on differences in susceptibility of turfgrass cultivars to various pathogens, particularly for cultivars included in the National Turfgrass Evaluation Program (1-3). Evaluations of turfgrass disease resistance typically are based on comparisons of disease intensities among cultivars at one or more assessment times. While these data are valuable, relatively few published reports exist where turfgrass cultivars were evaluated for recovery (postepidemic vegetative regrowth of symptomless tissue) (5) following a disease outbreak. Model studies conducted to date (5,14) have focused on turfgrass recovery in the absence of curative fungicide applications. Although quick recovery without fungicide is preferable, knowledge of how turfgrass cultivars perform following fungicide application could also be important for management regimes where fungicides are used. This could be particu-

larly important in implementing turfgrass integrated pest management programs, whereby certain diseases may be allowed to develop until some action threshold before a curative fungicide application is made.

Dollar spot, caused by *Sclerotinia homoeocarpa* F. T. Bennett, is a common and destructive disease of creeping bentgrass (*Agrostis palustris* Huds.) (17,19). Although cultivars vary in their susceptibility, none is considered completely resistant to *S. homoeocarpa* (19). A severe dollar spot outbreak can affect the quality of playing surfaces, influence aesthetic appearance, allow weed encroachment in turfgrass swards, and even cause plant death (18).

The reactions of many creeping bentgrass cultivars to *S. homoeocarpa* have been well characterized in recent years (1-3,8,10,11). However, published studies where creeping bentgrass cultivars were evaluated for recovery from disease outbreaks are lacking. Knowledge of the recuperative potential of creeping bentgrass cultivars would be valuable in implementing an integrated disease management program on golf courses.

This paper reports the results of field studies to evaluate bentgrass cultivars for recovery following outbreaks of dollar spot in both the absence and the presence of a curative fungicide application. Although

the study included entries of four *Agrostis* spp., this paper reports results obtained for creeping bentgrass, the most widely used bentgrass species in the United States. Preliminary reports for all four *Agrostis* spp. are available (9,12).

MATERIALS AND METHODS

Cultural conditions. Twenty cultivars (commercially cultivated as well as experimental lines) of four species of bentgrass (*Agrostis* spp.) were established in a Maury silt loam at the University of Kentucky Spindletop Research Farm as part of the 1989 National Bentgrass Fairways and Tees Evaluation. The number of entries and species represented were the following: 15 entries of *A. palustris*, one entry of *A. capillaris* L. (browntop bentgrass), one of *A. castellana* Boiss. & Reut. (dryland bentgrass), and three of *A. tenuis* Sibth. (colonial bentgrass). Entries were seeded at 25 kg/ha on 21 September 1989 in plots measuring 2.4 × 3.7 m and arranged in a randomized complete block design with three replicates. Two autumn applications of urea (73 kg N/ha at each application) were made annually after establishment; acceptable turfgrass quality was maintained without additional fertilizer applications. Plots were maintained at a height of 1.3 cm and were irrigated as necessary. Weather conditions were monitored at the UK Spindletop Agricultural Weather Station located within 100 m of the test site.

Evaluation of recovery. Dollar spot developed from natural inoculum until epidemics were well established (initial disease intensities provided in data tables). In 1991 and 1993, each plot was bisected into two 1.8 × 2.4 m subplots, and the initial disease intensity was assessed by counting infection centers in three randomly placed 929 cm² quadrats in each subplot. In 1992, pretreatment disease intensity was assessed by counting infection centers in one randomly placed quadrat within each subplot and in one quadrat along the line bisecting the whole plot. These three observations were averaged prior to analysis to provide an estimate of the initial disease intensity for each whole plot. The eastern (1991 and 1993) or western (1992) subplot of each plot was treated within 24 h with the ergosterol biosynthesis inhibitor fungicide cyproconazole at 0.76 kg a.i./ha (Sentinel 40 WDG) in 1,018 liters of water per ha using a hand-held sprayer fitted with 8003E nozzles (Spraying Systems, Inc.,

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Baltimore, MD). Infection centers were counted again in each subplot 6 to 14 days posttreatment. Data for separate quadrats within each subplot were averaged for each assessment date prior to analysis.

Data analysis. To assess recovery from dollar spot, disease intensity estimates for each cultivar were analyzed independently in each experiment. Data were analyzed by cultivar using analysis of variance for a randomized complete block design after first checking appropriate statistical assumptions. For each cultivar, posttreatment disease intensities in both treated and nontreated subplots were compared with each other and with initial disease intensities using the Waller-Duncan *k*-ratio *t* test (16).

In 1992, initial pretreatment disease intensities taken from the whole plot were compared to posttreatment estimates taken from each subplot. In order to evaluate the validity of this analysis, data on initial disease intensity for the entire experiment in both 1991 and 1993 were analyzed following a split block design (13); main plots were replicate and cultivar, and the strip plot was subplot position (east versus west). The main effect for position and the interaction term for cultivar $\times$ position

were used to test the hypothesis that subplot position had an effect on dollar spot intensity.

Recuperative potential of a cultivar from dollar spot was expressed as a percentage of disease intensity at the start of each experiment, $\%RECOV_t = [(DI_0 - DI_t)/DI_0]100$, where $\%RECOV_t$ = percent recovery on day *t*, DI_0 = mean initial disease intensity and DI_t = mean disease intensity on day *t*. Scatter plots and linear regression models (15) were evaluated to test for relationships between the level of partial resistance to dollar spot (as measured by DI_0) and recuperative potential ($\%RECOV_t$). Separate regression analyses were conducted for fungicide-treated and untreated subplots for all posttreatment assessment dates.

RESULTS

1991 experiment. Several cultivars—Lopez, National, Pennncross, Penneagle, Pro/Cup, Providence, and 88 CBE—showed significant ($P \leq 0.05$) recovery over a 10-day period only when treated with cyproconazole (Table 1). During the same period, significant recovery without fungicide was exhibited by Cobra, Regent, and SR 1020, but even greater recovery (P

≤ 0.05) was observed in these cultivars with cyproconazole treatment. Carmen, Emerald, and Viper exhibited similar responses to those described above, but they were not readily characterized because of the overlap of statistical groupings among treatment means. Putter and TAMU 881 exhibited statistically equivalent levels of recovery with or without fungicide treatment. The median daily maximum air temperature and total rainfall during the 10-day test period were 32.2°C and 1.1 cm, respectively.

1992 experiment. The lack of significant effects for position and cultivar $\times$ position ($P > 0.20$) in the initial disease intensity data collected during 1991 and 1993 (Table 2) validated the acceptability of comparing data collected for whole plots on 3 August 1992 with data collected from subplots on 11 August 1992 and 17 August 1992. Two weeks after treatment, Lopez, Pro/Cup, and Putter exhibited significant recovery only where fungicide was applied (Table 3). Penneagle and SR 1020 exhibited significant recovery without fungicide, but even greater recovery was observed with cyproconazole treatment. Cobra, Emerald, National, Regent, TAMU 881, Viper, and 88 CBE exhibited statistically equivalent levels of recovery in both fungicide-treated and nontreated subplots, although disease levels in Emerald and TAMU 881 after the 2-week period of study were higher than would be acceptable for a high-quality sward. Carmen and Pennncross did not exhibit statistically significant recovery after 2 weeks, even when treated with cyproconazole; high variability in disease intensity may have contributed to the lack of significant differences in these two cultivars. The response of Providence was not readily characterized because of overlap of statistical groupings among treatment means. The median daily maximum air temperature and total rainfall during the 14-day test period were 26.7°C and 7.4 cm, respectively.

1993 experiment. Twelve of 15 cultivars exhibited no significant change in disease intensity without fungicide, and none exhibited recovery to acceptably low levels without fungicide during the 13-day test period (Table 4). Pro/Cup and SR 1020 exhibited some statistically significant recovery without fungicide but required fungicide treatment to recover to levels during the test period that would be acceptable for high-maintenance swards. In untreated subplots of the cultivar National, disease intensity increased during the test period, the only instance where this was observed during our study. The median daily maximum air temperature and total rainfall during the 13-day test period were 31.1°C and 3.0 cm, respectively.

Test of association between partial resistance and recovery. No consistent relationship was observed between the level of partial resistance to dollar spot and recu-

Table 1. Recovery of creeping bentgrass cultivars from outbreaks of dollar spot during 1991

Cultivar	Number of infection centers per m ²			
	1 August 91		11 August 91	
	West subplot (untreated)	East subplot (untreated)	West subplot (untreated)	East subplot (treated 2 Aug) ^y
Lopez	222 a ^z	183 a	193 a	42 b
National	119 a	105 a	88 a	13 b
Pennncross	208 a	244 a	173 a	19 b
Penneagle	244 a	228 a	195 a	19 b
Pro/Cup	198 a	198 a	224 a	40 b
Providence	191 a	189 a	143 a	31 b
88 CBE	118 a	149 a	148 a	15 b
Cobra	184 a	174 a	93 b	9 c
Regent	192 a	182 a	125 b	33 c
SR 1020	243 a	216 a	108 b	17 c
Carmen	225 a	252 a	126 ab	15 b
Emerald	212 a	170 ab	93 bc	22 c
Viper	189 a	157 b	136 b	14 c
Putter	228 a	209 a	87 b	34 b
TAMU 881	173 a	203 a	60 b	2 b

^y Subplots treated on 2 August with 0.3 kg of cyproconazole per ha.

^z Means within a row (=cultivar) followed by the same letter are not significantly different using the Waller-Duncan *k*-ratio *t* test ($k = 100$, $P = 0.05$).

Table 2. Analysis of variance of pretreatment data on intensity of dollar spot in 20 bentgrass cultivars

Source	df	Mean squares ^y	
		1991	1993
Replicate	2	24.31	205.4
Cultivar	19	297.2**	227.8**
Rep $\times$ cultivar (error a)	38	26.52	14.87
Position ^z	1	0.0750	75.21
Rep $\times$ position (error b)	2	18.20	29.72
Cultivar $\times$ position	19	7.786	7.458
Experimental error (error c)	38	8.590	6.840
Total	119		

^y ** = $P \leq 0.01$.

^z Data were collected separately for the eastern and western sides of each plot.

perative potential as measured by the variable %*RECOV*_i (analyses not shown). This was the case in both fungicide-treated and untreated subplots.

DISCUSSION

During these studies, three general patterns of recovery from dollar spot outbreaks were commonly observed among creeping bentgrass cultivars: (i) significant recovery during the test period only with fungicide treatment; (ii) some statistically significant recovery without treatment but significantly greater recovery with fungicide treatment; and (iii) statistically equivalent recovery with or without fungicide treatment. In a few cases, certain cultivars showed no recovery or even exhibited an increase in dollar spot intensity in plots not treated with fungicide.

Environmental conditions affected the ability of creeping bentgrass cultivars to recover from dollar spot. In 1991 and 1993, nearly all cultivars tested recovered more quickly when treated with cyproconazole than when left untreated. In contrast, nearly half of the cultivars in 1992 exhibited the same level of recovery in both fungicide-treated and untreated subplots. Weather conditions during the 1992 test period were cooler and wetter than in other years of the study, which may have favored growth and recovery of this cool-season turfgrass. The temperatures observed in 1992 were more favorable for shoot and root growth of creeping bentgrass than those recorded in 1991 and 1993 (4,7). Adequate soil moisture may have also played a role in the quick recovery observed in 1992. Although the trial was irrigated as needed, temporary drought conditions developed occasionally during the warmer, drier conditions that occurred in 1991 and 1993. Such stress would have favored continued disease development during the 1991 and 1993 test periods (6,17–19), necessitating fungicide protection in many cultivars.

In 1992, pretreatment disease intensities taken from whole plots were compared to posttreatment estimates taken from the treated and untreated subplots. Although there was no effect of subplot position (east versus west) on disease intensity, we concluded that the experimental approach taken in 1991 and 1993—that is, separate pretreatment estimates of disease intensity for each subplot—is preferable for evaluating varietal recovery following a curative fungicide application. Even in the absence of evidence for a position effect in the analysis of variance, one cultivar in 1991 (Viper) and another in 1993 (Providence) exhibited different pretreatment disease levels in eastern versus western subplots. We concluded that these exceptions were probably due to natural variability in the occurrence of dollar spot, and that they did not negate the overall value of the 1992 data. Nevertheless, a more critical evalua-

tion of a cultivar's recovery potential with and without fungicide is possible if pretreatment estimates are available for both treated and untreated subplots.

We observed no consistent association between the level of partial resistance to *S. homoeocarpa* and recuperative potential among the 15 cultivars tested. This result indicates that the ability to recover from dollar spot is not directly related to the ability of creeping bentgrass cultivars to restrict pathogen activity and disease development. Cultivars exhibiting high recuperative potential may combine a high rate of foliar growth with partial resistance to *S. homoeocarpa*, a hypothesis worth testing in future studies on recovery of turfgrass cultivars from disease. The relatively rapid recovery we observed suggests healthy

tillers and leaves were being produced by surviving crowns and stolons, although detailed studies to understand how recovery occurs in creeping bentgrass would be useful. It would be of interest to know whether cultivars that exhibit quick recovery have a higher density of live crowns and/or stolons, more aggressive stoloniferous growth into diseased areas, or more rapid production of foliage from crowns. Furthermore, knowledge of the role of partial resistance in promoting recovery would be valuable. We concur with Burpee (5) that recovery of turfgrasses from a disease outbreak is a manifestation of disease tolerance rather than host plant resistance, since recuperative potential did not show a consistent association with the level of partial resistance.

Table 3. Recovery of creeping bentgrass cultivars from outbreaks of dollar spot during 1992

Cultivar	Number of infection centers per m ²				
	3 Aug 92 (whole plot measurement)	11 Aug 92		17 Aug 92	
		West subplot (untreated)	East subplot (treated 4 Aug) ^y	West subplot (untreated)	East subplot (treated 4 Aug)
Lopez	72 a ^z	43 ab	18 ab	55 ab	10 b
Pro/Cup	155 a	32 b	18 b	50 ab	34 b
Putter	99 a	61 bc	25 cd	68 ab	19 d
Penneagle	60 a	29 bc	18 bc	36 b	11 c
SR 1020	139 a	72 bc	40 cd	101 b	28 d
Cobra	64 a	22 ab	18 b	14 b	3 b
Emerald	235 a	75 b	57 b	139 b	80 b
National	25 a	18 ab	11 bc	3 cd	0 d
Regent	46 a	18 b	14 b	18 b	6 b
TAMU 881	209 a	154 ab	97 bc	103 bc	47 c
Viper	42 a	25 b	18 bc	9 cd	2 d
88 CBE	52 a	36 ab	29 ab	10 b	1 b
Carmen	105 a	65 a	36 a	57 a	52 a
Pennncross	128 a	46 ab	36 b	78 ab	40 ab
Providence	45 ab	40 ab	18 ab	62 a	4 b

^y Subplots treated on 4 August with 0.3 kg of cyproconazole per ha.

^z Means within a row (=cultivar) followed by the same letter are not significantly different using the Waller-Duncan *k*-ratio *t* test (*k* = 100, *P* = 0.05).

Table 4. Recovery of creeping bentgrass cultivars from outbreaks of dollar spot during 1993

Cultivar	Number of infection centers per m ²					
	24 Jun 93		30 Jun 93		7 Jul 93	
	West subplot (untreated)	East subplot (untreated)	West subplot (untreated)	East subplot (treated 25 Jun) ^y	West subplot (untreated)	East subplot (treated 25 Jun)
Carmen	160 a ^z	189 a	152 a	129 a	142 a	8 b
Cobra	110 ab	139 a	98 a	61 bc	90 ab	1 c
Emerald	146 abc	174 a	155 ab	101 bc	83 c	2 d
Lopez	163 a	151 a	138 a	103 a	128 a	15 b
Pennncross	169 ab	230 a	180 ab	133 b	123 b	4 c
Penneagle	80 ab	130 a	89 ab	39 ab	97 ab	6 b
Providence	76 bc	157 a	86 ab	89 ab	109 ab	3 c
Putter	131 a	143 a	123 a	99 a	112 a	6 b
Regent	103 a	90 a	89 a	30 b	115 a	2 b
TAMU 881	187 a	192 a	180 a	111 b	153 ab	13 c
Viper	103 a	107 a	116 a	72 a	104 a	3 b
88 CBE	94 a	109 a	93 a	104 a	76 a	8 b
Pro/Cup	184 a	182 a	164 ab	128 bc	125 c	6 d
SR 1020	177 a	192 a	164 ab	133 bc	104 c	1 d
National	22 bc	32 b	57 a	53 a	58 a	3 c

^y Subplots treated on 25 June with 0.3 kg of cyproconazole per ha.

^z Means within a row (=cultivar) followed by the same letter are not significantly different using the Waller-Duncan *k*-ratio *t* test (*k* = 100, *P* = 0.05).

The ability of creeping bentgrass cultivars to recover following dollar spot outbreaks under field conditions appears to be a complex, variable attribute. Only one cultivar (SR 1020) exhibited the same recovery pattern in each of 3 years; 10 of 15 cultivars exhibited the same recovery pattern in 2 of the 3 years of testing. We found that the ability of cultivars to recover from dollar spot varied under different environmental conditions. We postulate that recuperative potential also varies under different agronomic management regimes. While recovery was found to vary from year to year, the ability to recover quickly from a disease outbreak could be a valuable varietal trait, particularly if the cultivar possesses other important traits but inadequate levels of resistance to a particular pathogen. The potential for quick recovery from disease would be especially valuable if it can sometimes occur without need for a curative fungicide application, as was found with several cultivars.

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