

2019 December Progress Report: Ontario Turfgrass Research Foundation

Title: Assessing the Impact of Bentgrass Disease Tolerance on Fungicide Management of Dollar Spot

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Key Points:

- Threshold-based application of fungicide to control dollar spot reduced the total number of applications per year compared to a calendar-based program.
- Additionally, cultivars that were less susceptible to dollar spot further reduced the total number of applications under threshold-based programs. Reductions ranged from 22 to 78% depending on the cultivar and trial-year.
- Moreover, the level of disease control on some cultivar-threshold fungicide program combinations (including the next spray-day threshold) was similar to the respective calendar program.
- A work plan is being developed with an economist to determine cost differences among the various cultivar-fungicide treatment combinations in both trials.

This research project addresses these objectives:

1. determining the feasibility of using threshold-based fungicide applications on fairway turf to control dollar spot disease across a range of host (bentgrass cultivar) susceptibility and
2. evaluating the economic differences in annual fungicide inputs related to dollar spot susceptibility across bentgrass cultivars.

In 2018 and 2019, data was collected from a trial seeded in 2014 with two factors (bentgrass susceptibility to dollar spot and fungicide program) arranged in a 6 x 3 factorial using a randomized complete block design with four replications in 2018 and six replications in 2019. The cultivars used for the bentgrass susceptibility factor included: 'Capri' colonial bentgrass, 'Declaration' creeping bentgrass, '007' creeping bentgrass, 'Shark' creeping bentgrass, 'Penncross' creeping bentgrass, and 'Independence' creeping bentgrass. The factor of fungicide program included the levels of one calendar- and two threshold-based programs.

A second trial was seeded in August 2018 and designed with the same factors (bentgrass susceptibility and fungicide programming). The experiment was arranged in a 9 x 3 factorial using a randomized complete block design with four replications. The bentgrass factor included eight cultivars and one blend of bentgrass: 'Declaration and Independence (standards from the trial initiated in 2018), 'Flagstick', 'Chinook', 'Pure Select', 'Luminary', and 'T1' creeping bentgrass along with 'Musket' colonial bentgrass and the blend 'PennTrio' creeping bentgrass (Penncross, 'Penneagle II', and 'PennLinks II'). This new trial also included the factor of fungicide program that included the levels of a calendar-based and two threshold-based programs. Data was collected for this new trial from May through November 2019.

The trial established in 2014 had been inoculated in previous years but disease developed naturally on plots during 2018 and 2019. The border around this trial was inoculated with finely ground oats colonized by the dollar spot pathogen applied uniformly using a drop spreader on 10 July 2018, and 25 July and 12 September 2019 to increase disease pressure. The second trial (seeded in August 2018) was inoculated by uniformly distributing infested oats using a hand-shaker bottle on 6 April 2019.

The two threshold-based programs in both trials differed by the timing of fungicide re-application once the disease threshold was reached: one threshold program re-applied fungicide within 24 hours of reaching the threshold and the second threshold program re-applied at the next scheduled spray-day (emulating a weekly [i.e., Monday] spray-day at a golf course operation). The calendar-based program applied fungicide every 21-days from late-May through early-November for a total of 9 applications each year. A non-fungicide level (untreated check) was also included to accurately document disease epidemics throughout the season but was not part of the factorial design. Data collection was initiated when disease was first observed on 15 May 2018 (first trial) and 30 May 2019 (both trials) .

An average infection center diameter was used to quantify the total area of active-dollar spot infection within each plot during 2018 using the equation: total damage = (estimated average radius of active infection centers per plot)<sup>2</sup> × 3.14 × number of active-infection centers per plot. However, this method underestimated the total active-infection area when the diameter of infection centers varied greatly in size. Thus, assessment of disease damage was modified at the end of 2018 growing season to measure the diameter of each infection center per plot and calculate total damage as:  $\sum_{n=1} (3.14 \times r_n^2)$ , where r represents the radius of an active-infection center. Disease outbreaks were determined as a period when active infection area was higher than the damage threshold (sum of all reps) from any treatment in that rating date.

## Results

### Trial seeded in 2014

Threshold-based applications reduced the total number of applications per year compared to the calendar-based program, and the cultivar affected the extent of the reduction; Declaration received the lowest number of fungicide applications (2 to 3 per year) while Independence required the greatest number of applications (5 to 6 per year) during 2018 and 2019. Thus, fewer threshold-based fungicide applications were made on cultivars that were less susceptible to dollar spot (Table 1).

Fungicide program was the dominant factor that influenced dollar spot outbreaks over the two years; 21 disease outbreaks occurred on threshold treatments while no outbreaks occurred on calendar-based treatments (Tables 2 and 3). When differences between threshold programs were apparent, outbreaks typically were more severe for the next spray-day program. The dollar spot response (measured as area under the disease progress curve [AUDPC]) on plots treated with threshold fungicide programs were dependent on the cultivar factor during 13 of the 21 outbreaks and primarily indicated that disease outbreaks occurred when the environment conditions were conducive to disease and a given cultivar was no longer protected by fungicide (typically more than 21-d after previous application; Tables 4 and 5). Declaration, 007, Capri, Shark, Penncross and Independence ranked among the cultivars (either as a main effect or an interaction with fungicide program) with the most severe disease during 1, 1, 5, 6, 7, and 10 of the 21 outbreak periods, respectively (Table 6). Thus, a cultivar with higher susceptibility was more likely to sustain the most severe disease during outbreaks (Tables 4 and 5).

### Trial Seeded in 2018

The first-year data (2019) for the second trail indicated that both threshold programs reduced the number of applications compared to the calendar-based program (Table 7). Additionally, less susceptible cultivars (Declaration, Flagstick, Musket, Chinook and Luminary) further reduced the number of applications compared to more susceptible cultivars (T1, PennTrio, Pure Select and Independence).

All three fungicide programs differed with respect to the total AUDPC (Table 8). Generally, fungicide applied based on a calendar program had the lowest level of disease, while the next spray-day threshold program had a greater level of disease than 24-hour threshold program. However, disease response to the fungicide programs also depended on the cultivar/blend (Table 8). Musket was the only cultivar that had a low level of disease across all fungicide programs. For the total AUDPC, Flagstick, PennTrio and Declaration had a low and similar level of disease across both the calendar and threshold 24-hour fungicide program, whereas Chinook, Independence, T1, Pure select and Luminary had a greater level of disease under both threshold programs than the calendar program. Surprisingly, Pure Select and Luminary were the only cultivars that had a different dollar spot response for all fungicide programs.

Musket, Chinook, PennTrio, Declaration, Flagstick, Pure Select, Luminary, Independence and T1 had the most severe disease during 0, 1, 1, 2, 2, 3, 3, 5 and 6 of the 12 outbreaks, respectively (Table 9).

### Economic Impact

We have met with an economist to begin the process of determining the difference in cost among the cultivar by fungicide program treatments.

## 2020 Plan of Work

Treatments and data collection will be continued for a third and second year for the trials seeded in 2014 and 2018, respectively. Additionally, we expect to complete the economic analysis of treatments in the trial seeded in 2014 after the third year of data collection has been completed.

Table 1. The total number of threshold-based fungicide applications on six bentgrass cultivars treated either within 24-hours or on the next spray-day (Monday) after the damage threshold (314 mm<sup>2</sup> in 2018 and 471 mm<sup>2</sup> in 2019) from dollar spot was reached during 2018 and 2019.

Cultivars	Threshold Fungicide <sup>†</sup> Timing <sup>*</sup>			
	2018		2019	
	24 hours	Next spray-day	24 hours	Next spray-day
	----- number of applications -----			
Declaration	3	2	2	2
Capri	4	4	3	3
007	4	4	3	3
Shark	4	4	3	5
Penncross	5	4	4	4
Independence	6	6	5	5

<sup>†</sup>Tank mix of fluazinam at 0.8 kg a.i. ha<sup>-1</sup> (Secure 4.2SC @ 0.5 fl oz / 1,000 sq ft) and vinclozolin at 1.5 kg a.i. ha<sup>-1</sup> (Curalan 50WG @ 1.0 oz / 1,000 sq ft) used for fungicide application.

<sup>\*</sup>The timing of fungicide application after 314- or 471-mm<sup>2</sup> of damage was observed across 4 or 6 replications in 2018 and 2019, respectively. Calendar-based program applied fungicide every 21-days from 21 May through 4 Nov. 2018 and 20 May through 4 Nov. 2019 for total of 9 applications per year.

Table 2. Active dollar spot infection measured as area under disease progress curve (AUDPC) as affected by six bentgrass cultivars and three fungicide programs for disease outbreaks between 15 May to 2 Nov. 2018 on turf managed as a fairway in North Brunswick NJ.

ANOVA Source	5/17- 5/27 <sup>†</sup>	7/4 -7/9	7/18- 7/20	7/24- 8/1	8/1 -8/9	8/22- 8/25	8/30- 9/11	9/11- 9/18	9/20- 9/24	9/27- 9/28	10/5- 10/31	Total
	----- probability of a significant <i>F</i> test -----											
Cultivar	NS	***	NS	NS	**	*	*	NS	NS	*	***	***
Fungicide Program (FP) <sup>¶</sup>	NS	*	***	***	***	*	***	***	NS	*	***	***
Cultivar x FP	NS	*	*	NS	***	NS	NS	***	*	***	***	***
C.V.(%)	116	222	158	138	128	195	100	133	296	144	105	76
Cultivar‡	----- area under disease progress curve -----											
Capri	1416	13 b	21	501	45 c	2 b	743 a	390	39	39 ab	4769 b	7968 b
Declaration	450	27 b	25	388	69 c	38 b	204 c	175	248	9 bc	416 c	2049 c
007	833	24 b	27	513	126 bc	19 b	360 bc	220	34	17 abc	2499 bc	4672 bc
Shark	943	36 b	50	563	151 bc	28 b	592 ab	247	29	47 a	5604 b	8296 b
Penncross	477	2 b	57	153	432 a	52 b	609 ab	11	188	37 abc	11522 a	13532 a
Independence	1375	294 a	86	23	314 ab	162 a	100 c	368	8	7 c	3631 bc	6368 bc
LSD	NS	120	NS	NS	199	80	355	NS	NS	31	4098	4490
Fungicide Program												
Calendar	1106	0 b	0 b	6 b	0 b	1 b	9 b	1 c	7	21 b	188 b	1341 b
Threshold 24-h	757	97 a	103 a	418 a	108 b	94 a	563 a	207 b	112	44 a	828 b	3330 b
Threshold Next Spray-day	878	101 a	30 b	647 a	460 a	55 ab	735 a	498 a	155	14 b	13200 a	16772 a
LSD	NS	85	40	286	140	56	251	182	NS	22	2897	3174

\* Significant at  $p \leq 0.05$ ; \*\* significant at  $p \leq 0.01$ ; \*\*\* significant at  $p \leq 0.001$ ; NS: nonsignificant

<sup>†</sup> Dollar spot outbreak periods defined as days when the active infection area of any treatment exceeded the 314 mm<sup>2</sup> damage threshold.

<sup>‡</sup> Capri colonial bentgrass (*Agrostis capillaris* L.); Declaration, 007, Shark, Independence, and Penncross creeping bentgrass (*A.stolonifera* L.).

<sup>¶</sup> Calendar-based program applied every 21-days from 20 May to 4 November 2019. Threshold-based programs applied fungicide within 24 hours or the next spray-day (Monday) after disease damage exceeded 314 mm<sup>2</sup> across four replications in 2018.

Table 3. Active dollar spot infection measured as area under disease progress curve (AUDPC) as affected by six bentgrass cultivars and three fungicide programs for disease outbreaks between 30 May to 25 Nov. 2019 on turf managed as a fairway in North Brunswick NJ.

ANOVA Source	6/18	7/10	7/20	8/9	8/20	9/5	9/10	9/27	10/4	10/30	Total
	-6/28†	-7/15	-7/22	-8/12	-8/31	-9/6	-9/20	-10/2	-10/16	-11/13	
	----- probability of a significant <i>F</i> test -----										
Cultivar	*	*	*	***	NS	**	***	**	***	***	*
Fungicide Program (FP) <sup>¶</sup>	*	***	*	***	*	*	***	**	***	***	***
Cultivar x FP	NS	NS	NS	*	NS	*	***	***	***	***	NS
C.V.(%)	256	180	318	144	256	249	161	189	107	200	125
	----- area under disease progress curve -----										
<u>Cultivar<sup>‡</sup></u>											
Capri	314 b	360 a	2 c	6 c	186 ab	9 b	27 b	39 bc	1028 b	20 c	1991 bc
Declaration	5 b	38 b	11 bc	20 c	270 ab	5 b	0 b	13 c	411 c	211 c	983 c
007	335 b	144 b	7 bc	60 bc	461 ab	1 b	16 b	89 abc	1570 a	20 c	2702 bc
Shark	798 ab	81 b	108 ab	99 b	316 ab	13 b	565 a	135 ab	74 c	1305 b	3495 abc
Penncross	2095 a	224 ab	4 c	47 bc	592 a	5 b	18 b	174 a	551 bc	58 c	3769 ab
Independence	1121 ab	139 b	160 a	237 a	16 b	42 a	796 a	44 bc	376 c	2320 a	5253 a
LSD	1319	197	102	75	521	21	253	103	477	567	2517
<u>Fungicide Program</u>											
Calendar	0 b	0 c	1 b	14 b	1 b	0 b	10 b	2 b	5 b	2 b	34 c
Threshold 24-h	1070 a	163 b	49 ab	94 a	450 a	16 a	51 b	113 a	906 a	118 b	3050 b
Threshold Next Spray-day	1263 a	331 a	95 a	126 a	471 a	21 a	650 a	132 a	1096 a	1848 a	6012 a
LSD	932	139	72	53	368	15	179	73	337	613	1780

\* Significant at  $p \leq 0.05$ ; \*\* significant at  $p \leq 0.01$ ; \*\*\* significant at  $p \leq 0.001$ ; ns: nonsignificant

† Disease outbreak periods defined as days when dollar spot active infection area of any treatment exceeded the 471 mm<sup>2</sup> damage threshold.

‡ Capri colonial bentgrass (*Agrostis capillaris* L.); Declaration, 007, Shark, Independence, and Penncross creeping bentgrass (*A. stolonifera* L.).

¶ Calendar-based program applied every 21-days from 20 May to 4 Nov. 2019. Threshold-based programs fungicide applied within 24 hours or the next spray-day (Monday) after disease damage exceeded 471 mm<sup>2</sup> across six replications in 2019.

Table 4. Dollar spot response, measured as area under disease progress curve, on six cultivars treated with three fungicide programs from 15 May to 2 Nov. 2018 on turf managed as a fairway in North Brunswick NJ.

Cultivar <sup>†</sup>	Fungicide Program <sup>‡</sup>	7/4-7/9	7/18-7/20	8/1-8/9	9/11-9/18	9/20-9/24	9/27-9/28	10/5-10/31	Total
----- area under disease progress curve -----									
Capri	Calendar	0 b	0 c	0 d	5 e	0 b	25 cd	353 e	2480 f
Declaration	Calendar	0 b	0 c	0 d	0 e	0 b	2 d	5 e	1006 f
007	Calendar	0 b	0 c	2 d	0 e	0 b	0 d	10 e	781 f
Shark	Calendar	0 b	0 c	0 d	0 e	5 b	27 cd	53 e	1377 f
Penncross	Calendar	0 b	0 c	0 d	0 e	31 b	53 bcd	113 e	476 f
Independence	Calendar	0 b	0 c	0 d	0 e	5 b	20 cd	593 e	1926 f
Capri	Threshold 24-h	39 b	53 bc	10 d	32 e	69 b	93 ab	167 e	2858 ef
Declaration	Threshold 24-h	74 b	49 c	97 cd	298 cde	7 b	0 d	1237 e	3024 ef
007	Threshold 24-h	59 b	41 c	130 cd	15 e	74 b	52 bcd	731 e	2938 ef
Shark	Threshold 24-h	61 b	63 bc	56 cd	5 e	56 b	115 a	5 e	2498 f
Penncross	Threshold 24-h	5 b	152 b	56 cd	32 e	466 a	2 d	1196 e	3095 ef
Independence	Threshold 24-h	343 a	258 a	302 cd	858 ab	0 b	0 d	1631 de	5569 ef
Capri	Threshold NSD <sup>¶</sup>	0 b	10 c	125 cd	1132 a	48 b	0 d	13759 bc	18567 bc
Declaration	Threshold NSD	7 b	25 c	110 cd	226 de	737 a	27 cd	5 e	2117 f
007	Threshold NSD	15 b	39 c	246 cd	645 bcd	29 b	0 d	6756 cd	10296 de
Shark	Threshold NSD	47 b	86 bc	398 bc	737 abc	27 b	0 d	16754 bc	21013 b
Penncross	Threshold NSD	0 b	19 c	1239 a	0 e	67 b	57 bc	33258 a	37027 a
Independence	Threshold NSD	538 a	0 c	642 b	245 de	20 b	0 d	8670 cd	11610 cd
	LSD	208	99	344	445	383	54	7097	7776

<sup>†</sup> Capri colonial bentgrass (*Agrostis capillaris* L.) and Declaration, 007, Shark, Independence, and Penncross creeping bentgrasses (*A. stolonifera* L.).

<sup>‡</sup> Calendar-based program applied every 21-days from 20 May to 4 Nov. 2019. Threshold-based programs applied fungicide within 24 hours or the next spray-day (Monday) after disease damage 314 mm<sup>2</sup> across four replications in 2018.

<sup>¶</sup> NSD, next spray-day

Table 5. Dollar spot response, measured as area under disease progress curve, on six cultivars treated with three fungicide programs from 30 May to 25 Nov. 2019 on turf managed as a fairway in North Brunswick NJ.

Cultivar <sup>†</sup>	Fungicide Program <sup>‡</sup>	8/9-8/12	9/5-9/6	9/10-9/20	9/27-10/2	10/4-10/16	10/30-11/13
----- area under disease progress curve -----							
Capri	Calendar	11 d	0 c	3 c	3 b	20 d	8 c
Declaration	Calendar	7 d	0 c	0 c	0 b	0 d	0 c
007	Calendar	13 d	0 c	8 c	0 b	5 d	3 c
Shark	Calendar	15 d	0 c	10 c	0 b	3 d	0 c
Penncross	Calendar	18 d	0 c	10 c	0 b	0 d	0 c
Independence	Calendar	23 d	0 c	26 c	8 b	0 d	0 c
Capri	Threshold 24-h	3 d	5 bc	0 c	18 b	524 d	7 c
Declaration	Threshold 24-h	27 d	0 c	0 c	3 b	502 d	633 c
007	Threshold 24-h	128 cd	2 bc	32 c	138 b	2154 ab	8 c
Shark	Threshold 24-h	98 cd	2 bc	222 c	385 a	28 d	3 c
Penncross	Threshold 24-h	34 d	0 c	0 c	101 b	1497 bc	36 c
Independence	Threshold 24-h	274 b	91 a	51 c	34 b	729 cd	20 c
Capri	Threshold NSD <sup>¶</sup>	3 d	23 bc	79 c	96 b	2540 a	44 c
Declaration	Threshold NSD	26 d	15 bc	0 c	34 b	731 cd	0 c
007	Threshold NSD	40 d	0 c	7 c	129 b	2552 a	49 c
Shark	Threshold NSD	183 bc	38 b	1462 b	19 b	191 d	3912 b
Penncross	Threshold NSD	90 cd	16 bc	44 c	422 a	156 d	139 c
Independence	Threshold NSD	413 a	37 b	2311 a	90 b	406 d	6941 a
	LSD	129	36	438	179	826	1501

<sup>†</sup> Capri colonial bentgrass (*Agrostis capillaris* L.) and Declaration, 007, Shark, Independence, and Penncross creeping bentgrasses (*A. stolonifera* L.).

<sup>‡</sup> Calendar-based program applied every 21-days from 20 May to 4 Nov. 2019. Threshold-based programs applied fungicide within 24 hours or the next spray-day (Monday) after disease damage exceeded 471 mm<sup>2</sup> across six replications in 2019.

<sup>¶</sup> NSD, next spray-day



Table 6. The number of outbreaks when a cultivar, either as a main effect or in an interaction with fungicide program, was ranked among the most severely diseased cultivars during the 21 outbreaks of 2018 and 2019 on turf managed as a fairway in North Brunswick, NJ.

Cultivar <sup>†</sup>	Main Effect		Interactions with Fungicide Program	
	2018	2019	2018	2019
Declaration	0	0	1	0
Capri	1	1	2	1
007	0	0	0	1
Shark	1	2	2	1
Penncross	1	2	3	1
Independence	1	2	3	4

<sup>†</sup> Capri colonial bentgrass (*Agrostis capillaris* L.); Declaration, 007, Shark, Independence, and Penncross creeping bentgrass (*A. stolonifera* L.).

Table 7. The total number of threshold-based fungicide applications, number of applications that were delayed, and the time-delay between observation of the threshold and application of fungicide on eight cultivars and one blend of bentgrass treated within 24-hours or on the next spray-day (Monday) after the damage threshold (314 mm<sup>2</sup> of dollar spot damage per treatment) was reached on turf managed as a fairway in North Brunswick, NJ. Calendar-based program applied fungicide every 21-days 20 May through 4 Nov. 2019 for a total of 9 applications.

Cultivars <sup>†</sup>	Threshold Timing	Total fungicide <sup>‡</sup>		Time-delay between threshold and fungicide application <sup>§</sup>		
		applications	Applications delayed <sup>¶</sup>	Average	Minimum	Maximum
		----- # -----		----- days -----		
Declaration	24 hours	5	2	0.6	1	2
Flagstick	24 hours	5	0	0	-	-
Musket	24 hours	5	0	0	-	-
Chinook	24 hours	5	3	1.2	1	4
Pure Select	24 hours	7	1	0.1	-	1
Luminary	24 hours	5	2	0.4	-	1
T1	24 hours	7	1	0.3	-	1
PennTrio	24 hours	7	0	0	-	-
Independence	24 hours	7	1	0.1	-	1
Declaration	Next spray-day	5	4	3.8	3	6
Flagstick	Next spray-day	5	5	3.8	2	5
Musket	Next spray-day	5	4	2.2	2	5
Chinook	Next spray-day	5	5	4.2	3	6
Pure Select	Next spray-day	7	6	3.4	2	5
Luminary	Next spray-day	5	5	4.2	2	6
T1	Next spray-day	6	4	1.5	2	3
PennTrio	Next spray-day	6	4	1.5	2	3
Independence	Next spray-day	7	6	2.9	2	5

<sup>†</sup> Musket colonial bentgrass (*Agrostis capillaris* L.); Declaration, Flagstick, Chinook, Pure Select, Luminary, T1, and Independence creeping bentgrass (*A. stolonifera* L.); PennTrio, blend of Penncross, Penneagle II, and PennLinks II creeping bentgrass.

<sup>‡</sup> Tank mix of fluazinam at 0.8 kg a.i. ha<sup>-1</sup> (Secure 4.2SC @ 0.5 fl oz / 1,000 sq ft) and vinclozolin at 1.5 kg a.i. ha<sup>-1</sup> (Curalan 50WG @ 1.0 oz / 1,000 sq ft) used for fungicide application.

<sup>¶</sup> The number of fungicide applications that were delayed due to weather and/or the treatment schedule (next spray-day); 0 indicates fungicide applied within 24 hours of when threshold damage was observed.

<sup>§</sup> The average time between the threshold (314 mm<sup>2</sup> damage) being observed and fungicide application was calculated as the sum of all days delayed divided the total number of applications.

Table 8. Total dollar spot infection, measured as area under disease progress curve (AUDPC), as effected by nine bentgrasses and three fungicide programs during twelve disease outbreaks (days when dollar spot active infection area of any treatment exceeded the 314 mm<sup>2</sup> damage threshold) between 17 May to 25 Nov. 2019 on turf managed as a fairway in North Brunswick NJ.

ANOVA Source	5/25- 6/5	6/18- 6/28	7/1 -7/5	7/8 -7/17	8/2 -8/5	8/7 -8/14	8/19	8/23 -8/29	8/29 -9/3	9/5 -9/23	9/25 -10/14	10/28 -11/13	Total
	----- probability of a significant <i>F</i> test -----												
Cultivar <sup>†</sup>	***	***	***	***	***	***	**	***	***	**	***	***	***
Fungicide Program (FP)	***	***	***	***	***	***	NS	***	***	***	***	***	***
Cultivar x FP	*	***	***	***	**	***	***	**	*	***	***	***	*
C.V.(%)	110	132	103	112	127	80	543	139	113	142	142	89	63
	----- area under disease progress curve -----												
<u>Fungicide Program<sup>‡</sup></u>													
Calendar	6 b	0 b	6 c	3 b	4 b	278 c	0 b	7 b	99 b	87 b	31 b	0 c	522 c
Threshold 24-h	686 a	1210 a	166 b	617 a	145 a	532 b	9 a	259 a	294 a	233 b	1092 a	549 b	5794 b
Threshold next spray-day	585 a	1022 a	296 a	746 a	141 a	839 a	0 b	228 a	129 b	998 a	1382 a	2616 a	8981 a
LSD	219	461	75	236	58	205	8	107	92	292	555	440	1506

\* Significant at p≤0.05; \*\* significant at p≤0.01; \*\*\* significant at p≤0.001; ns: nonsignificant

<sup>†</sup> Musket colonial bentgrass (*Agrostis capillaris* L.); Declaration, Flagstick, Chinook, Pure Select, Luminary, T1, and Independence creeping bentgrass (*A. stolonifera* L.); PennTrio blend of Penncross, Pennlinks II, Penneagle II.

<sup>‡</sup> Calendar-based program applied every 21-days from 20 May to 4 Nov. 2019. Threshold-based programs fungicide applied within 24 hours or the next spray-day (Monday) after disease damage exceeded 314 mm<sup>2</sup> across four replications in 2019.

Table 9. Dollar spot response, measured as area under disease progress curve, on nine bentgrasses treated with three fungicide programs from 17 May to 25 Nov 2019 on turf managed as a fairway in North Brunswick NJ.

Cultivar <sup>†</sup>	Fungicide Program <sup>‡</sup>	5/25 -6/5	6/18 -6/28	7/1 -7/5	7/8 -7/17	8/2 -8/5	8/7 -8/14	8/19	8/23 -8/29	8/29 -9/3	9/5 -9/23	9/25 -10/14	10/28 -11/13	Total
Declaration	Calendar	0 f	0 g	0 e	0 h	0 f	2 i	0 b	0 e	0 e	0 e	0 d	0 e	2 i
Flagstick	Calendar	0 f	0 g	0 e	0 h	7 f	46 i	0 b	0 e	0 e	0 e	32 d	0 e	85 i
Musket	Calendar	0 f	0 g	5 de	0 h	0 f	230 hi	0 b	12 e	148 ce	34 e	20 d	0 e	449 hi
Chinook	Calendar	0 f	0 g	0 e	0 h	0 f	49 i	0 b	0 e	61 de	5 e	0 d	0 e	115 i
Pure Select	Calendar	5 f	0 g	10 de	0 h	12 ef	401 g-i	0 b	12 e	278 b-d	280 e	181 d	0 e	1179 g-i
Luminary	Calendar	0 f	0 g	0 e	0 h	0 f	66 i	0 b	2 e	74 de	0 e	7 d	0 e	150 i
T1	Calendar	0 f	0 g	0 e	5 gh	0 f	404 f-i	0 b	29 e	112 c-e	27 e	0 d	0 e	578 hi
PennTrio	Calendar	5 f	0 g	0 e	0 h	0 f	287 g-i	5 b	5 e	82 de	15 e	10 d	0 e	408 hi
Independence	Calendar	44 ef	0 g	39 de	17 gh	20 d-f	1018 c-f	0 b	5 e	135 c-e	422 de	29 d	0 e	1729 g-i
Declaration	24-hours	82 ef	1893 b-e	142 c-e	365 e-h	0 f	209 hi	81 a	0 e	0 e	622 c-e	10 d	898 c-e	4301 e-i
Flagstick	24-hours	463 d-f	5 g	153 c-e	44 gh	93 d-f	1045 b-e	0 b	47 e	483 ab	0 e	1852 bc	44 e	4229 e-i
Musket	24-hours	500 d-f	78 fg	322 bc	61 gh	12 ef	710 d-h	0 b	52 e	371 bc	0 e	1230 cd	10 e	3347 e-i
Chinook	24-hours	112 ef	3079 a-c	112 c-e	475 c-h	20 d-f	544 e-i	0 b	15 e	385 bc	0 e	1549 b-d	0 e	6290 c-f
Pure Select	24-hours	1038 bc	797 e-g	22 de	720 c-g	126 d-f	1316 b-d	0 b	185 de	670 a	573 c-e	142 d	1099 c-e	6686 c-f
Luminary	24-hours	306 ef	123 fg	86 de	103 e-gh	66 d-f	860 c-g	0 b	86 e	468 ab	0 e	3174 b	0 e	5272 d-g
T1	24-hours	1264 a-c	2782 a-d	447 b	1819 ab	410 ab	58 i	0 b	659 a-c	134 c-e	29 e	819 cd	565 de	8986 b-d
PennTrio	24-hours	980 b-d	684 e-g	74 de	782 c-f	184 c-e	34 i	0 b	448 cd	90 de	111 e	802 cd	486 e	4676 d-h
Independence	24-hours	1425 ab	1449 d-f	143 c-e	1186 bc	400 ab	15 i	0 b	838 ab	42 de	765 c-e	254 cd	1840 cd	8355 b-e
Declaration	NSD <sup>¶</sup>	10 f	3889 a	321 bc	660 c-h	15 ef	509 e-i	0 b	27 e	29 de	576 c-e	39 d	2150 c	8227 b-e
Flagstick	NSD	438 df	22 g	230 b-d	1110 b-d	104 df	1389 bc	0 b	17 e	49 de	1678 b	196 cd	5463 a	10697 bc
Musket	NSD	351 df	19 g	147 c-e	593 c-h	0 f	884 c-g	0 b	5 e	123 c-e	1295 b-d	821 cd	59 e	4295 e-i
Chinook	NSD	98 ef	3165 ab	111 c-e	711 c-h	25 d-f	558 e-i	0 b	0 e	5 de	1359 bc	140 d	1859 cd	8030 b-e
Pure Select	NSD	642 d-f	709 e-g	119 c-e	792 c-e	79 d-f	2224 a	0 b	34 e	517 ab	360 e	8323 a	3848 b	17646 a
Luminary	NSD	692 de	0 g	146 c-e	467 d-h	29 d-f	1658 ab	0 b	0 e	22 de	3201 a	186 cd	3528 b	9929 bc
T1	NSD	644 d-f	255 fg	794 a	68 f-h	517 a	208 hi	0 b	513 c	132 c-e	10 e	1146 cd	842 c-e	5129 d-g
PennTrio	NSD	567 d-f	262 fg	701 a	10 gh	314 bc	76 i	0 b	527 bc	94 de	59 e	1539 b-d	969 c-e	5118 d-g
Independence	NSD	1819 a	879 e-g	94 de	2301 a	190 cd	40 i	0 b	927 a	189 c-e	443 de	47 d	4827 ab	11757 b
	LSD	656	1382	226	716	174	616	24	322	275	876	1666	1318	4519

<sup>†</sup> Musket is a colonial bentgrass (*Agrostis capillaris* L.); Declaration, Flagstick, Chinook, Pure Select, Luminary, T1 and Independence are creeping bentgrasses (*A. stolonifera* L.); PennTrio is a blend of creeping bentgrasses 'Penncross', 'Pennlinks II', 'Penneagle II'.

<sup>‡</sup> Calendar-based program applied every 21-days from 20 May to 4 November 2019. Threshold-based programs fungicide applied within 24 hours or the next spray day (Monday) after disease damage exceeded 314 mm<sup>2</sup> across four replications in 2019.

<sup>¶</sup> NSD= next spray-day