CHAPTER 4. RESPONSE OF CREEPING BENTGRASS TO INORGANIC SOIL AMENDMENTS TOPDRESSED ON A SLOPED GREEN

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ABSTRACT

Putting green research is usually conducted on greens constructed with a flat surface. However, golf course greens are anything but flat. USGA root-zone specifications combined with a quality controlled mixing and construction produces a uniform root zone environment at the onset of green establishment. As the greens mature beyond the first year of establishment, uniformity inherently decreases. This is evident from the random nature of dry patches and other stressed patches observed on greens. The undulated and heterogeneous root zone media is prone to dry patch or black layer problems if the soil water and air are not properly managed. The objective of this study was to evaluate the effectiveness of inorganic soil amendments in controlling the dry patch on a sloped research green (SRG). The SRG contains a 7.0% slope facing north, a knoll, a 6.6% slope facing south, and a swale, the low portion to the south end of the green. The green was seeded with 'Crenshaw' creeping bentgrass (*Agrostis palustris* Huds.). The topdressing treatments include 80% of sand and

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20% (v/v) of peat, porous ceramic clay (PCC), calcined diatomaceous earth (CDE), zeolite clinoptilolite, and zeolite clinoptilolite preloaded with fertilizers (ZPF). Turf color and coverage were evaluated in 1999 and 2000 during the growing seasons and before and after two cycles of dry down treatments in the four areas on the green. During most of the growing season in 1999, ZPF treatment showed better turf color and coverage. This advantage was lost during the irrigated recovery period that followed two periods of water stress. It is possible that the extra 49 kg ha^{-1} of N in ZPF could have made turf quality appear better during most of the summer, but also predisposed the grass to more drought injury as evident from the lower quality ratings during the water stress period. The low turf quality of ZPF in the spring of 2000 may have been caused by high levels of Na and K which were 47.7 g kg^{-1} and 557.7 g kg^{-1} in the 0-2.5 cm of root zones, respectively. We did not find benefits of inorganic amendments used as topdressing materials to prevent dry patch problems on a sloped green.

KEYWORDS. Inorganic amendments, Sloped green, Soil amendment, Localized dry spots, Dry patch

INTRODUCTION

The GCSAA and USGA both have research programs directed at conducting research on actual golf courses. This is in response to surveys indication that 82% of the respondants feel that "research trials conducted on golf courses yield more accurate and useful information than the same trials conducted on university field plots". The logic behind this is that research plots seldom match up the amount of stresses in terms of traffic and pests.

Another obvious difference between the golf course greens and research plots is that the former are usually built on a undulated topography whereas the later are flat and uniform. The homogeneity of the root zone during construction gives way to heterogeneous conditions and different microenvironments that are expressed in distinct stressed areas of a putting green. It has been assumed that dry patch happens more often in the higher spot and black layer happens more often in the lower spot on an undulated golf green when water is improperly managed (Wilkinson and Miller, 1978; Cullinmore et al., 1990; Tucker et al., 1990; Berndt and Vargas Jr., 1992).

Soil amendments have been suggested for use in the golf green root zones since 1916 (Hurdzan, 1985). At the beginning sand was used to modify soil-based greens. Later on, organic and inorganic soil amendments were introduced to the sand-based root zones (Carrow, 1993). So far, research on the impact of inorganic amendments on soil physical properties has been restricted to limited products such as zeolite clinoptilolite (Ferguson et al., 1986; Huang and Petrovic., 1995) and calcined clay (Beard, 1973; Waddington et al., 1974) or in the laboratory (McCoy and Stehouwer, 1998). It is therefore of practical importance to know if application of soil inorganic amendments on an undulated golf green as topdressing can control the dry patch or black layer problems.

The optimum amount and distribution of inorganic material in the surface 5 cm of a green is not clearly understood. Li et al. (2000) reported positive effects of inorganic soil amendments on soil physical properties in a flat sand-based green. There is no information comparing the effects of inorganic soil amendments used as root-zone mixtures to that used as top dressing. The objective of this study was to investigate the effectiveness of dry patch control and soil physical properties when using peat, PCC, CDE, Zeolite clinoptilolite, and ZPF as topdressing materials on a research green that simulates actual contoured conditions.

MATERIALS AND METHODS

A sloped research green (SRG) was constructed at the Horticulture Research Station in 1997. The SRG was created to simulate the undulating topography that occurs on putting greens in many golf courses. A 30-cm sand-based root zone was positioned over a 10-cm gravel blanket that embeds 10-cm drain lines. The subgrade, gravel blanket, and sand root zone all follow the same contour. The SRG contains a 7.0% slope facing north, a knoll, a 6.6% slope facing south, and a swale, the low portion to the south end of the green (Figure 1). The green was seeded with 'Crenshaw' creeping bentgrass (*Agrostis palustris* Huds.) in September 1997. By August there was 100 percent turf cover and approximately 0.5 cm of thatch.

On 25 September 1998 the green was severely verticut. A 0.5 cm depth of topdressing material was immediately applied for each treatment following verticutting. The topdressing treatments include 80% of sand and 20% (v/v) of following materials: peat (Dakota Peat and Blenders, Grand Forks, ND), porous ceramic clay (PCC) (Profile, Profile Products LLC, Buffalo Grove, IL.), calcined diatomaceous earth (CDE) (Axis, Eagle-Picher Minerals, Reno, NV), zeolite clinoptilolite (ZeoPro, Zeoponix Inc. Louisville, CO.), and zeolite clinoptilolite preloaded with fertilizers (ZPF) (ZeoPro, Zeoponix Inc. Louisville, CO.). The sand has a pH of 8.2 and is calcareous. Particle size distribution falls within the United States Golf Association (USGA) specification (Hummel, 1993). The experiment is a randomized complete block design. Each treatment unit (plot) measures 12.2 by 1.8 m.

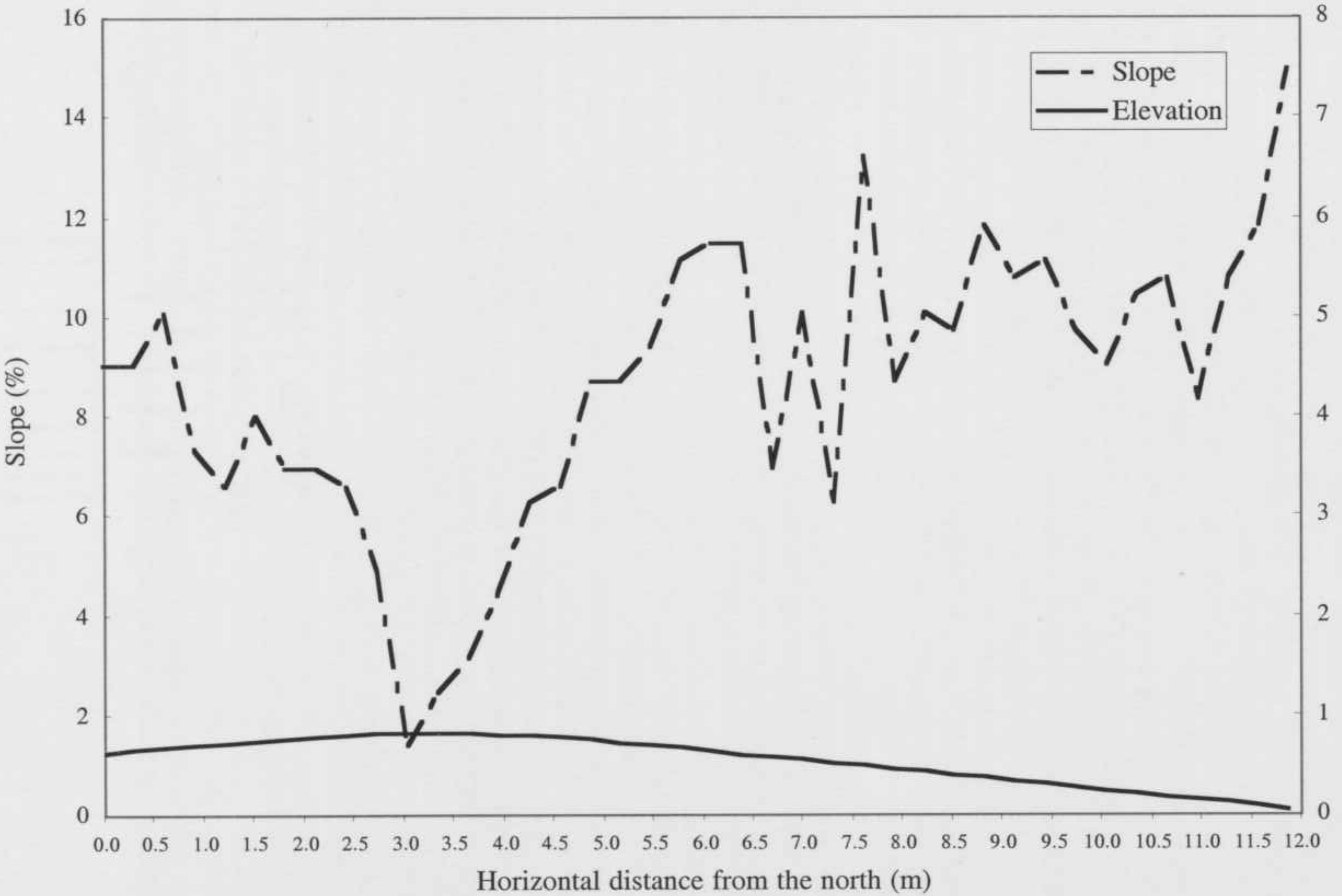

Figure 1. Contour dimensions of the sloped research green.

Due to winter desiccation, the entire green was overseeded with 98 kg ha^{-1} Of 'Crenshaw' creeping bentgrass in 1 April 1999. Mowing height was raised to 1.1 cm and gradually lowered to 0.5 cm by 23 August 1999. There were no apparent differences in winter injury among treatments. Treatments were topdressed every two weeks from 14 May to 30 September for a total of 2.5 cm in 1999. To smooth the green's surface and the depressions between plots, the entire green was topdressed with 0.2 cm of the original sand and a mat was dragged across all plots on 25 Oct 1999. The entire green was fertilized with a total of 215 kg ha^{-1} of N, 122 kg ha^{-1} of P_2O_5, and 176 kg ha^{-1} of K_2O. Since ZPF contains nutrients, this treatment actually received an extra 49 kg ha^{-1} of N, 24 kg ha^{-1} of P_2O_5, and 293 kg ha^{-1} of K_2O.

We created two cycles of water stress by withholding water in 1999. The first water stress was from 27 July to 2 August 1999, and the second water stress was from 28 August to 9 September 1999. Turf quality, color, and dry spots were rated throughout the growing season and right before and after each water stress on a scale of 0-9, where 9 = best, 6 = minimum acceptable, 0 = brown or dead.

In April 2000, soil samples were taken at the north side, the knoll and swale areas of each plot. Samples were separated into the top 2.5 cm and the bottom 12.5 cm. Soil moisture was measured by oven drying the samples at 105 °C for 24 hr. The soil materials were sent to Harris Lab. Lincoln, Nebraska for fertility analysis. In 2000, a total amount of 1.25 cm topdressing treatments were applied from May to September. Fertilizers were spread using a broadcaster during the spring and sprayed with a spoon-feeding program later on. The total amount applied during 2000 was 116 kg ha^{-1} of N, 44 kg ha^{-1} of P_2O_5, and 70 kg

ha^{-1} of K_2O, respectively, except that ZPF received additional 18 kg ha^{-1} of N, 8 kg ha^{-1} of P_2O_5, and 88 kg ha^{-1} of K_2O because the product is preloaded with fertilizer. The mowing height was adjusted to 0.3 cm. Similar to 1999, we created two cycles of water stress by withholding the water. The first water stress period was from 9 Aug. to 18 Aug. 2000, and the second water stress was from 1 Sept. to 6 Sept. 2000. We rated turf color and percent dry patch every two weeks. Turf quality ratings were also taken before and after each water stress period. Volumetric water contents were measured in 0-5 cm, 0-10 cm and 0-20 cm depth before and after water stress using a TDR100 equipment (Campbell Scientific Inc. Logan, Utah.). Water content also was measured before and after one watering event in order to determine the water holding capacity and movement within the soil profile of the sloped green.

RESULTS

Turf color quality

As shown in Table 1, there were no differences in turf color among treatments prior to the first water stress at 15 July 1999. Immediately after the first water stress, the north side, knoll, and swale areas showed differences in color quality with ZPF as the best. After the second water stress on 9 September, those differences for the north side and swale disappeared, however, the south side now showed differences with CDE having the best turf. The south slope of the SRG showed the poorest color because of the most wilting injury. During the recovery period ZPF has the lowest color ratings compared to peat, CDE, and zeolite on 16 Sept. 1999 and compared to peat on 14 Oct. 1999. By 11 November, all plots were the same in color quality. In 2000, there were no turf color differences among the

Table 1 Turf color quality (0-9 scale, 9 = best, 6 = minimum acceptable, 0 = brown) in four areas of a sloped green topdressed with inorganic soil amendments in 1999.

Treatment	Before water stress	After 1st water stress	After 2nd water stress	Recovery period		
	July 15, 99	Aug. 2, 99	Sept. 9, 99	Sept. 16, 99	Oct. 14, 99	Nov. 11, 99
			North side			
Peat	6.7	6.7	6.2	7.5	8.7	6.0
CDE†	6.5	6.3	6.5	7.5	8.2	6.0
PCC‡	6.5	6.2	5.8	7.2	8.7	6.0
Zeolite§	6.7	6.2	5.7	7.2	8.5	6.0
ZPF¶	7.0	7.5	6.0	7.2	8.5	6.0
$LSD_{0.05}$	NS	0.4	NS	NS	NS	NS
			Knoll			
Peat	7.0	6.5	5.7	4.5	6.2	7.3
CDE	7.0	6.0	4.3	7.0	7.3	5.7
PCC	7.0	5.2	4.8	5.2	7.8	5.8
Zeolite	7.0	5.5	4.7	6.5	6.3	5.5
ZPF	7.0	6.5	5.0	4.8	7.0	5.7
$LSD_{0.05}$	NS	0.6	NS	0.7	NS	NS
			South side			
Peat	7.0	6.0	4.3	7.0	8.3	6.3
CDE	7.0	6.2	5.7	7.7	7.2	6.7
PCC	7.0	6.0	4.8	6.0	7.0	6.0
Zeolite	7.0	6.0	4.7	6.7	7.3	6.8
ZPF	7.0	6.7	4.7	5.5	7.0	6.3
$LSD_{0.05}$	NS	NS	0.8	1.0	0.8	NS
			Swale			
Peat	6.0	6.7	6.0	8.2	8.7	7.5
CDE	6.3	6.7	6.5	7.8	8.3	7.3
PCC	5.8	6.2	6.0	8.0	8.5	7.5
Zeolite	5.8	6.5	6.3	8.0	8.2	7.7
ZPF	6.5	7.2	6.2	8.0	8.2	7.5
$LSD_{0.05}$	NS	0.5	NS	NS	NS	NS

† CDE, calcined diatomaceous earth.

‡ PCC, porous ceramic clay.

§ Zeolite, Zeolite clinoptilolite.

¶ ZPF, Zeolite clinoptilolite preloaded with fertilizer.

treatments for each of the four areas on the sloped green (Table 2).

Turf cover

On the north side of the sloped green in 1999, turfgrass coverage of ZPF was the best (with least dry patch) before and after the first water stress. Following the second water stress, no quality differences were detected (Figure 2). On the knoll, there were no differences before the first water stress but the quality decreased after the first water stress to a point when only CDE had the highest acceptable quality at 9 September (Figure 3). On the south side of the sloped green, coverage of ZPF treatment was better than others after the first water stress but its quality decreased to the worst after the second water stress (Figure 4). There was no difference in turf coverage quality in the swale area except before the first water stress when ZPF treatment had the best quality (Figure 5).

In 2000, the north side, knoll, and swale showed no differences among amendment treatments before or after water stress (Figure 6, 7, and 9). Only during March to April did the ZPF treatment have higher dry patch percentage on the south side of the sloped green (Figure 8).

Root-zone nutrients and water status

There were no differences in nutrients among the treatments on the north side, south side and the swale. Therefore, the results that showed differences on the knoll only are reported (Table 3). Water content in the 0-15 cm depth was the highest for the ZPF treatment and lowest for the peat treatment. Sodium and K in the 0-2.5 cm depth of the ZPF treatment were 3.8 and 4.2 times that of the peat control, respectively. Sodium and K in the 0-2.5 cm depth of the zeolite treatment were 2.6 and 3.1 times that of the peat control, respectively.

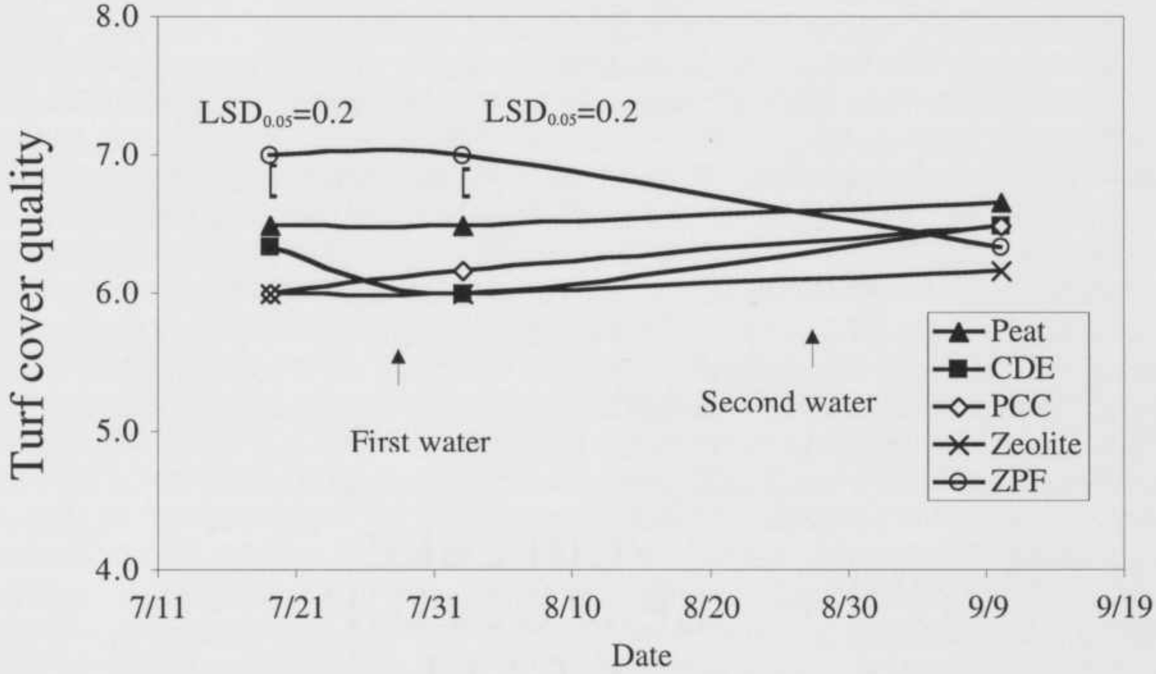

Figure 2. Bentgrass (*Agrostis palustris* Huds.) turf coverage in 1999 on the north side of a sloped research green topdressed with 80% of sand and 20% (v/v) of peat, calcined diatomaceous earth (CDE), porous ceramic clay (PCC), zeolite clinoptilolite (Zeolite) and zeolite clinoptilolite preloaded with fertilizers (ZPF), respectively.

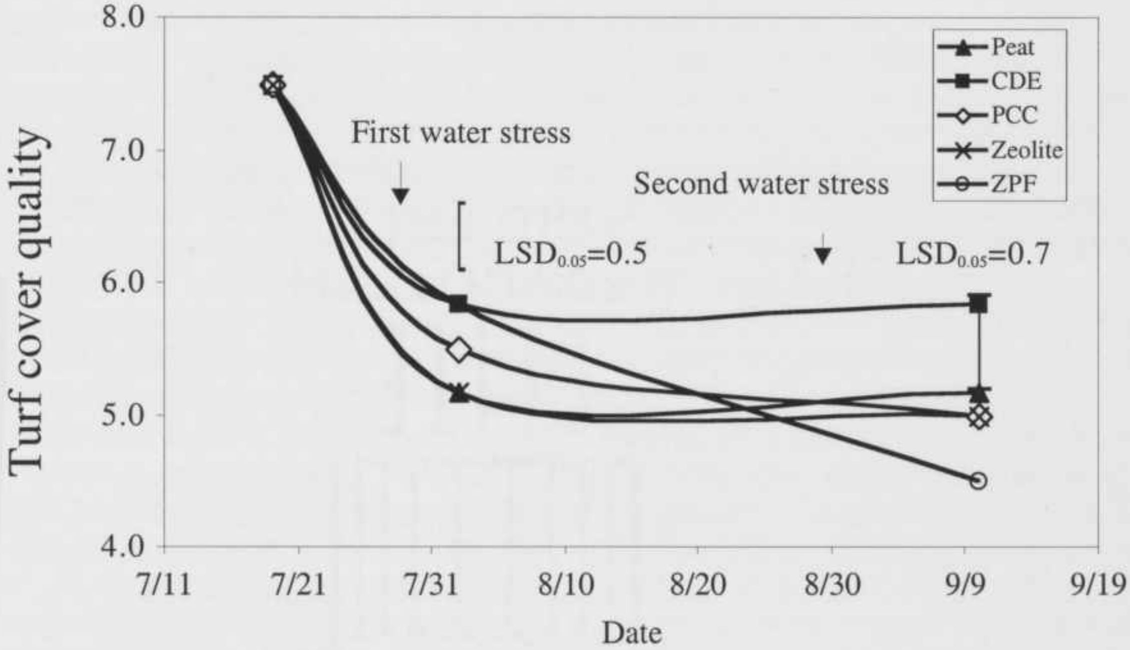

Figure 3. Bentgrass (*Agrostis palustris* Huds.) turf coverage in 1999 on the knoll of a sloped research green topdressed with 80% of sand and 20% (v/v) of peat, calcined diatomaceous earth (CDE), porous ceramic clay (PCC), zeolite clinoptilolite (Zeolite) and zeolite clinoptilolite preloaded with fertilizers (ZPF), respectively.

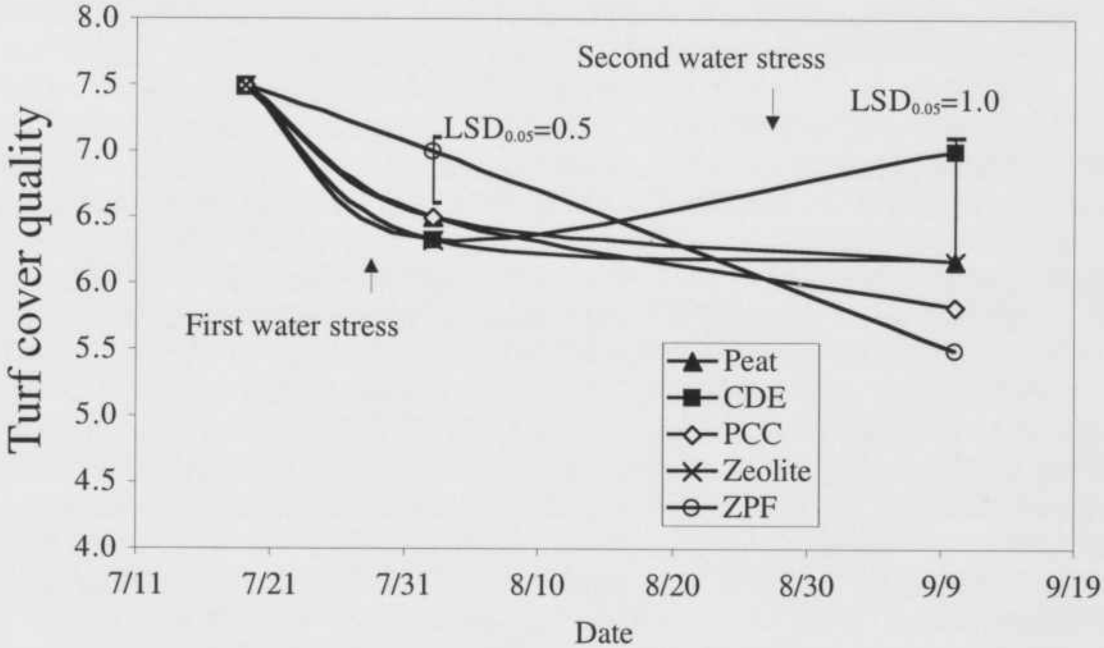

Figure 4. Bentgrass (*Agrostis palustris* Huds.) turf coverage in 1999 on the south side of a sloped research green topdressed with 80% of sand and 20% (v/v) of peat, calcined diatomaceous earth (CDE), porous ceramic clay (PCC), zeolite clinoptilolite (Zeolite) and zeolite clinoptilolite preloaded with fertilizers (ZPF), respectively.

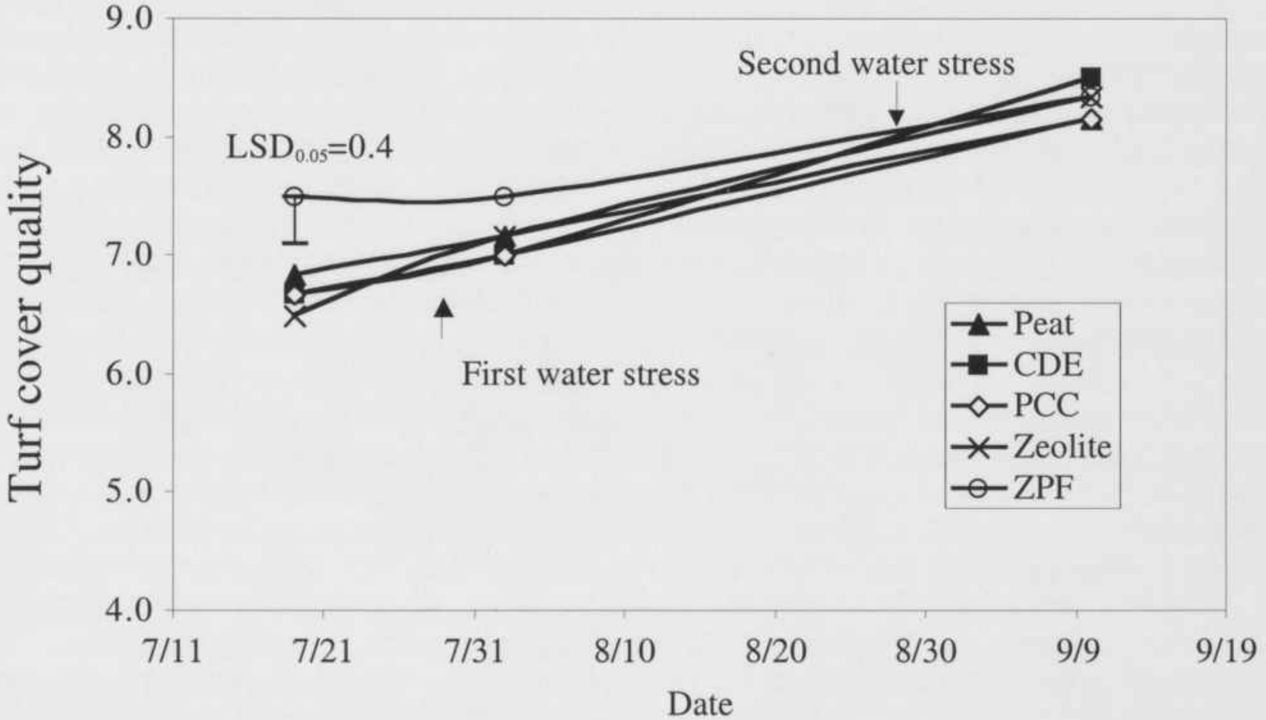

Figure 5. Bentgrass (*Agrostis palustris* Huds.) turf coverage in 1999 on the swale of a sloped research green topdressed with 80% of sand and 20% (v/v) of peat, calcined diatomaceous earth (CDE), porous ceramic clay (PCC), zeolite clinoptilolite (Zeolite) and zeolite clinoptilolite preloaded with fertilizers (ZPF), respectively.

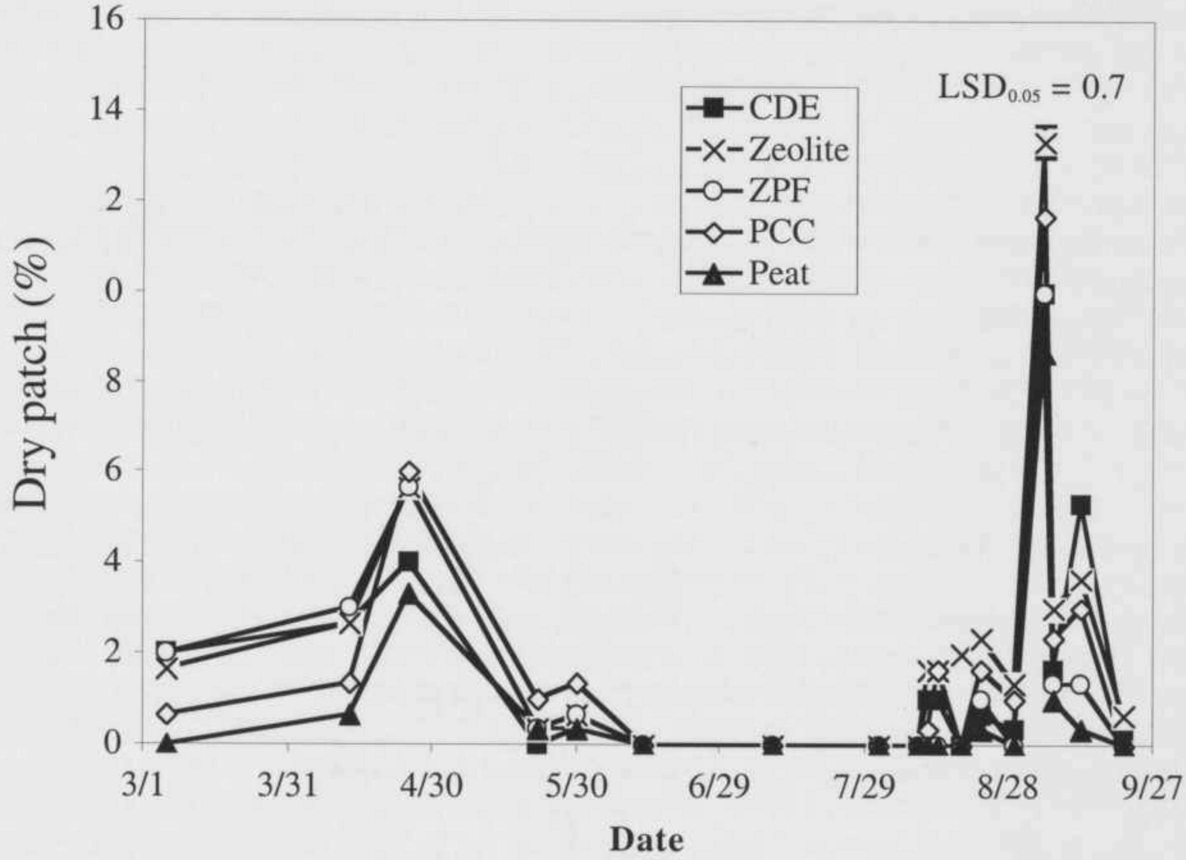

Figure 6. Bentgrass (*Agrostis palustris* Huds.) turf dry patch rate in 2000 on the north side of a sloped research green topdressed with 80% of sand and 20% (v/v) of peat, calcined diatomaceous earth (CDE), porous ceramic clay (PCC), zeolite clinoptilolite (Zeolite) and zeolite clinoptilolite preloaded with fertilizers (ZPF), respectively.

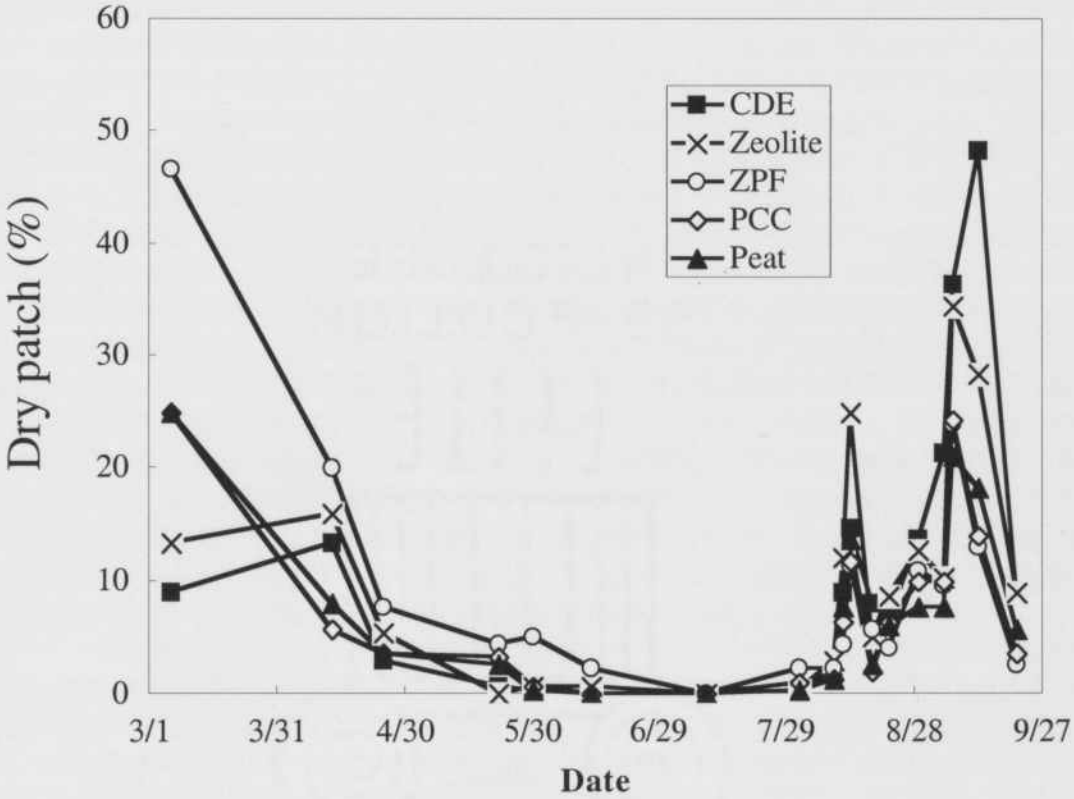

Figure 7. Bentgrass (*Agrostis palustris* Huds.) turf dry patch rate in 2000 on the knoll of a sloped research green topdressed with 80% of sand and 20% (v/v) of peat, calcined diatomaceous earth (CDE), porous ceramic clay (PCC), zeolite clinoptilolite (Zeolite) and zeolite clinoptilolite preloaded with fertilizers (ZPF), respectively.

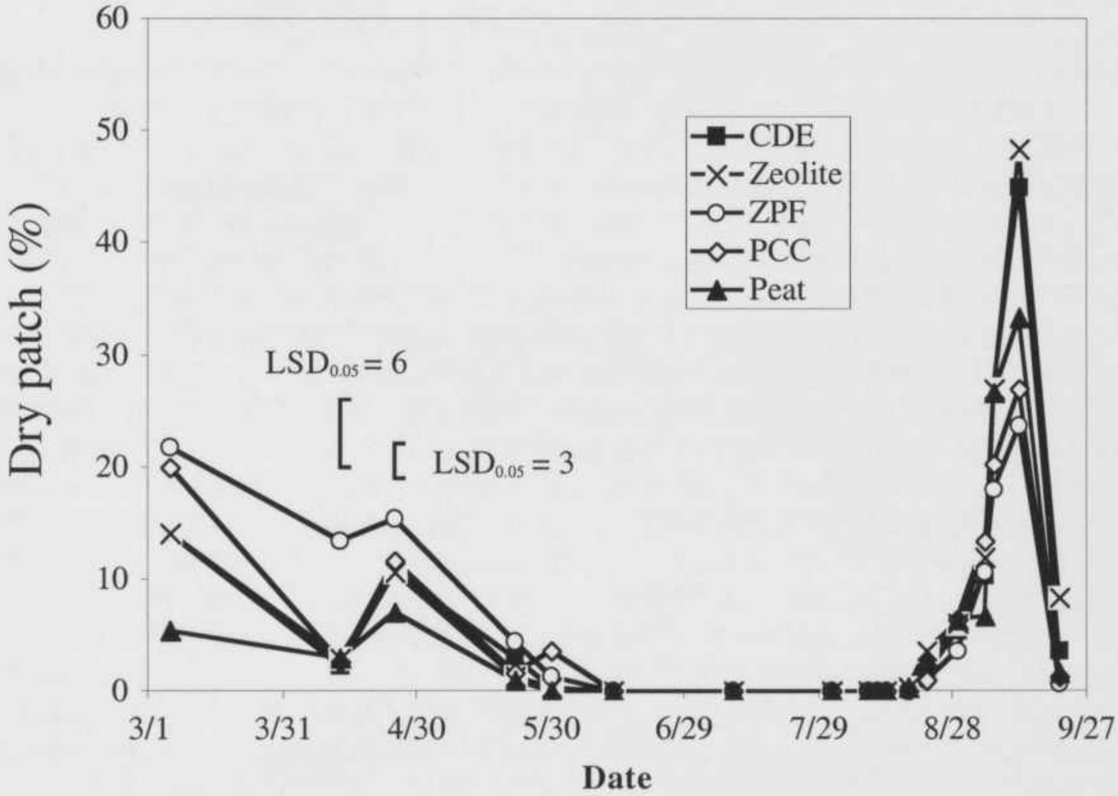

Figure 8. Bentgrass (*Agrostis palustris* Huds.) turf dry patch rate in 2000 on the south side of a sloped research green topdressed with 80% of sand and 20% (v/v) of peat, calcined diatomaceous earth (CDE), porous ceramic clay (PCC), zeolite clinoptilolite (Zeolite) and zeolite clinoptilolite preloaded with fertilizers (ZPF), respectively.

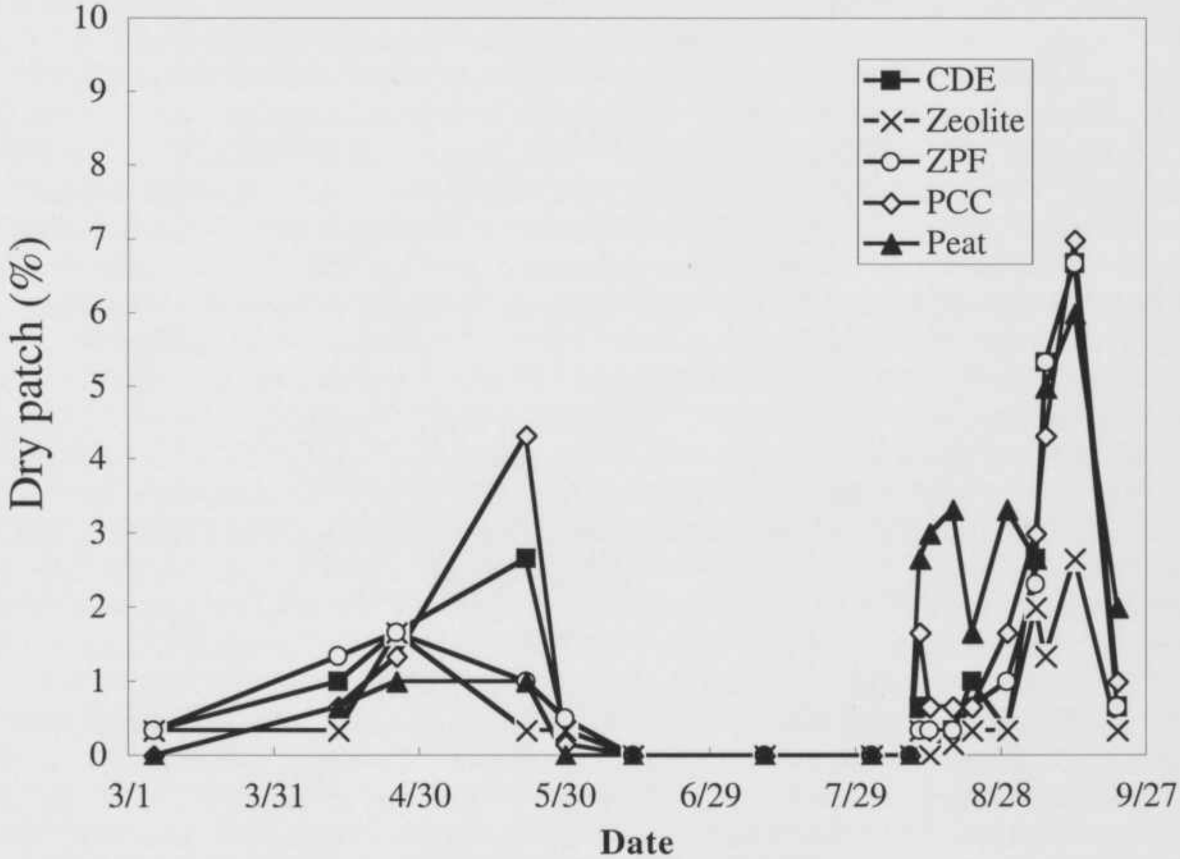

Figure 9. Bentgrass (*Agrostis palustris* Huds.) turf dry patch rate in 2000 on the swale of a sloped research green topdressed with 80% of sand and 20% (v/v) of peat, calcined diatomaceous earth (CDE), porous ceramic clay (PCC), zeolite clinoptilolite (Zeolite) and zeolite clinoptilolite preloaded with fertilizers (ZPF), respectively.

Table 2 Turf color quality (0-9 scale, 9 = best, 6 = minimum acceptable, 0 = brown) in four areas of a sloped green topdressed with inorganic soil amendments in 2000.

Treatment	Before water stress July 10, 00	After 1st water stress Aug. 18, 00	After 2nd water stress Sept. 6, 00	Recovering period Sept. 12, 00	Recovering period Sept. 21, 00
			North side		
Peat	7.7	7.0	6.0	5.7	7.0
CDE†	7.7	6.7	6.0	5.7	7.0
PCC‡	7.3	7.0	6.0	5.7	7.0
Zeolite§	7.7	6.3	6.0	5.3	7.0
ZPF¶	8.3	7.0	6.0	5.7	7.7
$LSD_{0.05}$	NS	NS	NS	NS	0.5
			Knoll		
Peat	6.7	7.0	6.0	5.0	6.0
CDE	6.3	6.3	6.0	5.0	6.0
PCC	6.0	6.7	6.0	5.3	6.0
Zeolite	6.3	6.3	6.0	5.0	6.0
ZPF	7.0	6.3	6.0	5.0	6.0
$LSD_{0.05}$	NS	NS	NS	NS	NS
			South side		
Peat	7.0	6.7	7.0	6.0	7.0
CDE	6.3	6.7	7.0	6.0	7.0
PCC	6.3	6.3	7.0	6.0	7.0
Zeolite	6.0	7.0	7.0	6.0	7.0
ZPF	7.0	6.7	7.0	6.0	7.0
$LSD_{0.05}$	NS	NS	NS	NS	NS
			Swale		
Peat	8.0	7.0	7.0	6.0	8.0
CDE	8.3	7.0	7.0	6.0	8.0
PCC	8.0	7.0	7.0	6.0	8.0
Zeolite	8.3	7.0	7.0	6.0	8.0
ZPF	8.7	7.0	7.0	6.0	8.0
$LSD_{0.05}$	NS	NS	NS	NS	NS

† CDE, calcined diatomaceous earth.

‡ PCC, porous ceramic clay.

§ Zeolite, Zeolite clinoptilolite.

¶ ZPF, Zeolite clinoptilolite preloaded with fertilizer

Phosphorus content in the 0-2.5 cm was higher in CDE treatment than other treatments except PCC. No difference existed among the treatments in the 2.5-15 cm depth for Na, K, or P. No differences in total soluble salts were found among the treatments.

No water content differences were found among treatments in all four areas on the sloped green after the water stress and the results are not reported here.

DISCUSSION

During most of the growing season in 1999, ZPF treatment showed better turf color and coverage. This advantage in turf quality gained under non-stressed conditions by ZPF was lost during the irrigated recovery period that followed two periods of water stress. The ZPF treatment had a total 264 kg ha^{-1} of N while the other treatments had 215 kg ha^{-1} of N. It is possible that the extra 49 kg ha^{-1} of N could have made turf quality appear better during most of the summer, but also predisposed the grass to more drought injuries as evident from the lower quality ratings during the water stress period. The extra 293 kg ha^{-1} of K in ZPF could also contributed to the lower quality of ZPF treatment after water stress.

In the absence of dry conditions the improved turf quality observed for ZPF was probably associated with higher levels of N and K in the product. In 2000, this advantage of ZPF disappeared when less topdressing material was used and a spoon-feeding fertilization program was started.

Furthermore it was shown that the carried-over low turf coverage in ZPF treatment was related to the high Na and K content during the spring of 2000 when water content in the ZPF treatment was actually higher than the other treatments. Since total soluble salts were not different among the treatments, Na toxicity may have been the reason for the higher dry

Table 3. Soil water content and fertility tested April 15, 2000 from the knoll of a sloped green topdressed with inorganic soil amendments.

Treatment	Water content	Soluble salts		Na		P		K	
		0-2.5 cm	2.5-15 cm	0-2.5 cm	2.5-15 cm	0-2.5 cm	2.5-15 cm	0-2.5 cm	2.5-15 cm
	$g\ kg^{-1}$	$mmhoms\ cm^{-1}$		$g\ kg^{-1}$					
Peat	36	0.2	0.1	12.7	8.7	9.0	9.3	132.3	52.7
CDE†	41	0.2	0.1	17.0	9.7	13.3	8.3	129.3	62.3
PCC‡	45	0.3	0.1	15.7	8.3	10.7	8.3	167.3	60.3
Zeolite§	46	0.2	0.1	32.7	13.0	9.3	9.0	405.0	86.0
ZPF¶	49	0.2	0.1	47.7	14.3	9.3	8.7	557.7	87.7
$LSD_{0.05}$	3	NS	NS	11.6	NS	2.7	NS	158.0	NS

† CDE, calcined diatomaceous earth.

‡ PCC, porous ceramic clay.

§ Zeolite, Zeolite clinoptilolite.

¶ ZPF, Zeolite clinoptilolite preloaded with fertilizer patch percentage in the ZPF treatment. Koski (1999) also reported that high Na in some zeolites may cause physical injury to turfgrass.

Although we have observed significant turf quality between the different areas on the sloped green, the results are not presented here. One reason is that investigating turf quality in different topography was not our primary objective in this study. Another reason is that the areas should be assigned as a random treatment in order to investigate the area effects. Furthermore the areas should be independent for the statistical model to be valid. Apparently the north side, the knoll, the south side and the swale are correlated which leads to less degrees of freedom.

Nevertheless, the sloped green provided a very good model to investigate water movement in a sand-based root zone media. It also is useful model to study the dry patch and black layer problems that are often noticed on undulated golf greens which are difficult to manage for the best water and air relationship. Further research is therefore needed to understand the development of localized dry patch and black layer by monitoring the water movement and distribution on an undulated golf green.

We did not find benefits of inorganic amendments used as topdressing materials to prevent dry patch problems on a sloped green. It by no means suggests that other beneficial physical properties did not exist. Future research may be needed to understand the thermal properties of the topdressing layers that are important in dissipating radiation energy during the hot seasons.

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