Evaluation of Diatomaceous Earth Topdressing for Cyanobacterial Suppression on Bermudagrass Putting Greens

Bulletin 1079 -- February 1999

Victor L. Maddox
Senior Research Assistant
MSU Plant and Soil Sciences

James M. Goatley, Jr.
Professor of Agronomy
MSU Plant and Soil Sciences

Jeffrey V. Krans
Professor of Agronomy
MSU Plant and Soil Sciences

Herbert W. Philley
Senior Research Assistant
MSU Plant and Soil Sciences

Research reported in this bulletin was supported by Mississippi Agricultural and Forestry Experiment Station project no. MIS-1325. The bulletin was was published by the Office of Agricultural Communications, a unit of the Division of Agriculture, Forestry, and Veterinary Medicine at Mississippi State University. It was edited and designed by Robert A. Hearn, publications editor. The cover was designed by George H. Taylor, chief illustrator and graphic artist.

Abstract

Diatomaceous earth (DE) and other soil amendments such as sand or fired clay are commonly used as topdressing materials for golf putting greens. In addition to physical changes in soil properties of the turfgrass root zone, these products may also exhibit algicidal/cyanobactericidal activity by improving water infiltration and/or by desiccation. The objective of this study was to evaluate DE as a cyanobactericide on a 'Tifgreen' bermudagrass [*Cynodon dactylon* (L.) Pers. x *transvaalensis* Burtt-Davy] putting green by making direct microscopic counts and visual ratings of algae/cyanobacteria populations. Percent turf cover and color were also recorded. Three treatments were applied biweekly to cored and non-cored plots over a 10-week period during the summers of 1995 and 1996: (1) DE alone; (2) DE in combination with chlorothalonil (tetrachloroisophthalonitrile); and (3) chlorothalonil alone. Compared to the check, all treatments showed decreasing trends in cyanobacterial numbers across weeks in 1995. However, there were no significant treatment differences within weeks until week 6, during and after which numbers in all treatments were significantly lower than the check. In 1996, cyanobacterial numeric trends declined across weeks, and by weeks 4 and 6 all treatments were significantly lower than the check. For weeks 8 through 10, numbers in the check and treatments receiving chlorothalonil showed fluctuations, while numbers in the DE treatment continued a significant decreasing trend. Turf discoloration was significant in the chlorothalonil treatment after five applications in 1995 and three applications in 1996. DE improved turf color and appears to mask some discoloration when used in combination with chlorothalonil.

Introduction

Algae and/or cyanobacteria are a common problem on golf putting greens. At one time, both algae and cyanobacteria were considered true algae, but now are recognized as very different organisms (Raven et al., 1981). Many species of algae and cyanobacteria inhabit putting greens (Baldwin and Whitton, 1992; Colbaugh et al., 1994a; Maddox et al., 1997). Algicides and/or fungicides are commonly used to suppress populations, and evaluations of many products have been conducted (Cameron and Julian, 1994; Colbaugh and Williams, 1993; Colbaugh et al., 1994bc; Elliott, 1994, 1995; Soika and Sanders, 1991; Vargas et al., 1986). Although they are not labeled and have potential to damage turf, hydrated lime and bleach have also been used.

Algae and cyanobacteria are phototrophic organisms, existing generally within the top 2 centimeters of the soil surface. Management practices that facilitate surface drying help prevent algal and cyanobacterial proliferation. These practices include reducing irrigation frequency, core aerification, and topdressing. Topdressing greens with sand and/or other soil amendments is a common practice, which may reduce algal and cyanobacterial populations by increasing water infiltration.

Sand is the most common topdressing amendment, but other products are available, such as diatomaceous earth (DE), which is also called diatomite. Information is available regarding the physical properties of DE (Koski and Keeley, 1992; Pease and Luepke, 1995; Ralston and Daniel, 1973; Waddington, 1992). Although this product has positive physical characteristics, no research information is available concerning its effects on cyanobacterial or algal numbers on putting greens. The objective of this study was to evaluate DE as a cyanobactericide on a 'Tifgreen' bermudagrass [*Cynodon dactylon* (L.) Pers. x *transvaalensis* Burrt-Davy] putting green by making direct microscopic counts and visual ratings of algae/cyanobacteria.

Materials and Methods

Putting Green Description

Two 'Tifgreen' bermudagrass [*Cynodon dactylon* (L.) Pers. x *transvaalensis* Burtt-Davy] putting greens with visible algae/cyanobacteria infestations were chosen for this study in 1995 and 1996. The study was conducted on a different green in 1996 to prevent residual treatment effects from 1995. Both experiments were located on the Mississippi State University Golf Course on greens mowed daily to 4.8 millimeters (3/16 inch). These greens were constructed with 80% sand and 20% peat. In 1996, the 'Tifgreen' bermudagrass green had areas seeded to common bermudagrass [*Cynodon dactylon* (L.) Pers.] because of extensive winterkill of the 'Tifgreen' bermudagrass the previous winter. At initiation of the study on July 5, 1995, turf cover was thin, ranging from 50% to 70%, with the remainder of the area covered by algae/cyanobacteria. In 1995, soil tests showed no deficiencies of extractable nutrients, except potassium (134 kilograms per hectare). Soil pH was 4.3. In 1996, areas seeded to common bermudagrass were thin, ranging from 30% to 40%, with visible algae/cyanobacteria colonization on the soil surface at initiation on July 23. As in 1995, blocks were selected based on uniformity of colony density and visible colonization within a block. Similar to 1995, a soil test showed no nutrient deficiencies, except potassium (62 kilograms per hectare). The soil pH was 5.3.

In 1995 and 1996, water soluble nitrogen (34-0-0) was applied at 2.44 grams of nitrogen per square meter uniformly over the area biweekly beginning July 5 through Sept. 12, 1995, and beginning July 23 through Oct. 1, 1996. Fertilizer was applied following treatment application and sample collection.

Experimental Design

The study was a split-plot in a randomized complete block design with repeated measures for 2 years (Table 1). There were four levels of the subplot factors (treatments) and two levels of the whole-plot factors (cored or non-cored). The study had three replications, and repeated measures were made biweekly over a 10-week period. Due to significant year-by-week interactions (Table 1), data were analyzed by year (Table 2). Week-by-treatment interactions were significant within year (Table 2); therefore, data were analyzed by week and

treatment (Tables 4-7). Since there were no missing data, the Analysis of Variance (ANOVA) procedure was used to analyze data (SAS, 1988a). Fisher's protected LSD
(P = 0.05) was used for mean separation following a significant *F* value. The Pearson correlation coefficient (SAS, 1988b) was used to correlate algal and cyanobacterial numbers, turf cover, and algal/cyanobacterial visual ratings (Table 3).

Treatment Application

Coring was conducted at study initiation with a Ryan GA-30 coring machine (Ransomes America Corp., Lincoln, NE) equipped with 1.6-centimeter-diameter hollow tines set on 7.6-centimeter spacing and penetrating to a depth of 10.2 centimeters. After coring, cores were raked in, and larger plant debris was removed. Subplots included: (1) DE at 244 kilograms per square meter; (2) DE at 244 kilograms per square meter, plus chlorothalonil at 1.44 grams of active ingredient (ai) per square meter; (3) chlorothalonil alone at 1.44 grams ai per square meter; (4) and an untreated check. The trade name of the DE used in this study was PSA^{TM} (Prescription Soil Amendment, Lakeland, FL), which has a particle size of 0.25 to 1 millimeter (medium to coarse), is chemically inert, and has a pH of 7. PSA has a bulk density of 0.37 milligram per cubic meter and porosity of 82% with no clay. The bulk density of PSA is much lower than sand (approximately 1.19 milligrams per cubic meter). Chlorothalonil applications were applied first with a boom sprayer at a volume of 280.5 liters per hectare (30 gallons per acre) and a pressure of 0.173 megapascal (25 pounds per square inch). After the chlorothalonil applications had dried, DE was uniformly applied across the designated plots with a drop spreader. Subplot treatments were applied biweekly beginning July 5 through Sept. 12, 1995, and beginning July 23 through Oct. 1, 1996.

Sampling and Rating of Putting Greens

Two 1.9- by 2.5-centimeter soil cores were collected before biweekly treatment applications from each experimental unit. Subsequent cores were collected next to previous cores to prevent location variation. Soil cores were analyzed under a light microscope (Bausch and Lomb Dynazoom Research Laboratory Microscope, Rochester, NY) for algal and cyanobacterial numbers by the following methods. Each core sample was placed in a 25- by 150-millimeter test tube, 25 milliliters of distilled water was added, and the tubes were shaken vigorously for 30 seconds. A microliter pipette (Pipetman 200; Rainin Instrument Co., Inc., MA) was used to immediately collect two 25-microliter drops of unsettled solution, which were placed on a microscope slide at opposite ends and covered with cover slips. Three microscope fields at 200X were analyzed from each drop (cover slip) to determine algal and cyanobacterial numbers. Live algal taxa enumerated were *Chlamydomonas* sp., *Hormidium* sp., *Cylindrocystis* sp., *Melosira* sp. (Syn. Aulacoseira), *Navicula mutica* Kütz., and *Hantzschia amphioxys* (Ehr.) Grun. Live cyanobacterial taxa enumerated were *Lyngbya* sp., *Nostoc* sp., and *Oscillatoria* spp. Filaments were counted as one. The 12 microscope fields from the 4 drops were combined and divided by 2. This number was transformed by multiplying by 42,580.11662 to estimate the number of algae or cyanobacteria present in a square centimeter. This number was calculated based upon the following information. The microscope field area is 0.66476 square millimeter with a cover area of 484.0 square millimeters. Based upon this and the 25-microliter drop, 0.034335 microliter is viewed in each microscope field. This number multiplied by 6 (number of fields counted for each tube) yields 0.20601 microliter, or the total amount of solution viewed from each tube. Since the surface of the soil core is diluted in 25 milliliters of water, then 25 milliliters divided by 0.00020601 milliliters yields 121,353.3324, the factor which would estimate the number on the entire soil core. This amount divided by 2.85 square centimeters (surface area of soil core) yields 42,580.11662, the factor which estimates the number of algae or cyanobacteria on a square centimeter of soil sample.

Visual ratings were taken at the time soil cores were collected. A visual rating was used for comparisons with the algal and cyanobacterial numbers by using correlation analyses (Table 3). These ratings ranged from 1 (no visible algae/cyanobacteria) up to 6 (complete mat of algae/cyanobacteria over plot area). Scores were significant for treatments in 1996 (Table 6). Percent turf cover was also recorded for correlation analyses. Turf color ratings were recorded at the 8th and 10th weeks in 1995 and the 2nd through 14th weeks in 1996 when discoloration of turf was observed as a result of treatment applications (Table 7). The color rating scale ranged from 1 = brown to 9 = dark green turf.

Results and Discussion

Coring

The effect of coring (whole plot) on cyanobacterial numbers, scoring, and percent turf cover was not significant ($P \leq 0.05$) nor were any interactions with coring as determined by analysis of variance (Tables 1 and 2). Although coring was not a significant factor in this study, it may be in studies where compaction is a problem. The greens used in this study were sand based and have no history of drainage problems. The fact that percent turf cover was not significant is also an indication that compaction was not a serious problem on this site.

Correlations

Correlations between cyanobacterial numbers, algal numbers, percent turf cover, and algal/cyanobacterial visual ratings were performed to assist in making inferences about associations between variables in this study (Table 3).

Percent turf cover was negatively correlated with cyanobacterial numbers in 1995 and 1996, but this correlation was significant only in 1996. This finding was expected since cyanobacteria and turf compete for light, and as turf cover increased, smaller light-harvesting organisms became shaded. Correlations between percent turf cover and algal numbers were significant, but they showed a negative correlation in 1995 and positive correlation in 1996. It is possible that the algae species counted were not as prolific as the cyanobacteria in the absence of turf cover. However, algal numbers in this study were low compared to cyanobacterial numbers, making it harder to interpret algal findings. In addition, it is probable that algal and cyanobacterial numbers are influenced by a number of factors including moisture, nutrients, light, and other organisms.

Visual ratings showed a strong significant negative correlation with percent turf cover in both 1995 and 1996. Since the lower ratings are better, this is a positive statement regarding the use of visual ratings. However, algal numbers were almost equally responsible for the correlation in 1995, since the correlation coefficients and probabilities between algal (0.15157 and 0.0749) and cyanobacterial (0.17869 and 0.0321) numbers were similar. This implies that visual ratings may not always differentiate between algae and cyanobacteria. This may be a problem since these organisms may not have the same response to various algicides/cyanobactericides. A good example of this is the negative correlation between algal and cyanobacterial numbers during this study in 1996 in the presence of control agents (chlorothalonil and DE). However, visual ratings showed a significant positive correlation in both 1995 and 1996 with cyanobacterial numbers. These organisms were apparently prominent organisms during this study. The most common cyanobacteria species (*Oscillatoria* spp.) in this study were dark in color, which can assist in making visual ratings. The results of this study raise some questions regarding the use of visual ratings for evaluating products designed to control algae and cyanobacteria. It is possible for one organism to proliferate during the decline of another, even in the presence of control agent(s). There is a possibility that certain species, or strains, have tolerance or resistance to certain products. The effects of other organisms upon these strains may be greater than that of the product(s). More research is needed to better understand the relationships between these organisms.

PSA and Chlorothalonil Treatment Effects

Algal numbers were low compared to cyanobacterial numbers and therefore used only in correlation analysis. Cyanobacterial numbers were greater and analyzed further in this study. Because of a significant correlation between cyanobacterial numbers and percent turf cover (Table 3), percent turf cover was used as the covariate in a covariance analysis for cyanobacterial numbers. Percent turf cover was not significant in the covariance analysis (data not shown) and not used in the final analysis of variance (ANOVA) procedures shown in Tables 1 and 2. For cyanobacterial numbers, there were significant year-by-week interactions (Table 1); therefore, years were analyzed separately (Table 2). Within year, there were significant week-by-treatment interactions both years. Cyanobacterial numbers are presented within year by week and by treatment (Tables 4 and 5). Visual ratings of treatments were significantly different in 1996 and presented in Table 6.

Treatment effects were significant for cyanobacterial numbers ($P \leq 0.05$) in 1995 and 1996. Within week, cyanobacterial numbers showed no significant differences between treatments at the initiation (Week 0) of this study in 1995 or 1996 (Tables 4 and 5). At initiation, numbers ranged from 745,100 to 844,500 filaments per square centimeter in 1995 and from 837,400 to 968,700 filaments per square centimeter in 1996. This finding is important since it indicates that there were no treatment differences across blocks at the time treatments were applied. Had significant differences occurred, the numeric aspects of the study would come under question.

In 1995, from the 6th week through the 10th week, numbers in the check were significantly higher compared to the other three treatments (Table 4). Numbers for the sixth week ranged from more than 1 million filaments per square centimeter in the check to 603,000 filaments in the chlorothalonil treatment and 554,000 filaments per square centimeter in the DE and DE plus chlorothalonil treatments. Numbers for the eighth week ranged from more than 1.21 million filaments per square centimeter in the check to between 759,000 and 596,000 filaments per square centimeter in the remaining treatments. At the 10th week, numbers ranged from 940,000 filaments per square centimeter in the check to between 433,000 and 575,000 filaments per square centimeter in the remaining treatments. Within treatments, the DE, DE plus chlorothalonil, and chlorothalonil treatments all showed numeric reductions, but only treatments receiving chlorothalonil were statistically significant. Conversely, numbers in the check treatment showed statistically significant increases between the initiation (749,000 filaments per square centimeter), the second and fourth week numbers (703,000 filaments per square centimeter), and the eighth week numbers (1,217,000 filaments per square centimeter). From these data, all treatments appear to decrease cyanobacterial numbers. There appears to be an initial numeric response to the treatments, which was significant in the treatments receiving chlorothalonil. This implies that some curative action may be involved with these products. However, a significant separation between the check and cyanobactericide treatments did not occur until week six, when numbers in the check increased. This implies some preventive mechanisms may be involved.

In 1996, an initial reduction comparable to 1995 was not observed. However, by week four, numbers in all treatments but the check had declined, a trend which continued through week six. After week six, only the DE treatment continued a decreasing numeric trend. It is not clear why numbers in the check fluctuated during this period. It is very likely that damage to the turf contributed to the numeric increase in the chlorothalonil treatment by adding light as a factor. The numeric trends of these two treatments and the check later in the year are followed closely by trends seen with visual ratings (Table 6). Although lower, the numeric trend in the combination treatment was close to that of the check. The DE in the combination treatment may have held numbers down, since numbers where higher during this same period in the chlorothalonil treatment. Similar numeric fluctuations in chlorothalonil treatments were observed in 1995.

Part of the numeric fluctuations in 1995 and 1996 may be a result of turf discoloration and damage from chlorothalonil treatments (Table 7). Although observed later in 1995, discoloration was significant by the 8th and 10th weeks. Compared to DE and the check, the chlorothalonil treatment showed significant turf discoloration. In 1996, significant discoloration was apparent by the sixth week. Similar to 1995, significant discoloration was apparent by the 8th and 10th weeks of the study in 1996. Discoloration in the chlorothalonil treatment was observed until the 14th week, 6 weeks after the last chlorothalonil treatments and after the first frost. Discoloration in the combination treatment was not as pronounced. It is possible that chlorothalonil absorption by DE was partly responsible. In addition, turf color in the DE treatment was slightly better than the check and may have also helped offset the discoloration in the combination treatment. The earlier and more pronounced discoloration in 1996 could be due to the use of common bermudagrass, a grass not adapted to the 4.8-millimeter cutting height used on the study area. Although these findings indicate that extended use of chlorothalonil may cause turf discoloration, it is not clear what causes the discoloration. In addition, more clarification on how DE causes a color response in bermudagrass is needed.

These data indicate that either chlorothalonil or DE may suppress cyanobacterial populations on putting greens. However, extended use of chlorothalonil may cause discoloration in 'Tifgreen' and common bermudagrass turfs under the conditions of this study. Again, common bermudagrass is not adapted for putting green mowing heights and was most likely under stress from close clipping. No discoloration was observed from DE at 244 kilograms per square meter in this study. In addition, DE may help alleviate turf discoloration from treatment with chlorothalonil. Slight reductions in cyanobacterial numbers early in the studies indicates possible desiccative or curative action. Continued use of DE might also reduce cyanobacterial numbers by improving turfgrass growing conditions through modifications of root zone properties.

References

Baldwin, N.A., and B.A. Whitton. 1992. Cyanobacteria and eukaryotic algae in sports turf and amenity grasslands: a review. J. of Applied Phycology 4:39-47.

Cameron, H.J., and G.R. Julian. 1994. The effects of four commonly used fungicides on the growth of cyanobacteria. Plant and Soil 78:409-415.

Colbaugh, P.F., and E.A. Williams. 1993. Chemical control of algal crusts. p. 257-261. *In*: International Turfgrass Soc. Res. J. Vol. 7. Palm Beach, Fl.

Colbaugh, P.F., E.L. Williams, and C. Allen. 1994a. Algae associated with algal crusts on a Texas golf green. *In*: Texas Turfgrass Res. - 1993. The Texas A&M University System, College Station, TX.

Colbaugh, P.F., S.P. Metz, and M.A. Cotton. 1994b. Control of algal crusts on golf course greens with Algaen-X. *In*: Texas Turfgrass Res. - 1993. The Texas A&M University System, College Station, TX.

Colbaugh, P.F., E.A. Williams, and S.P. Metz. 1994c. Efficacy of Algaen-X for controlling algal crusts on golf greens. *In*: Texas Turfgrass Res. - 1994. The Texas A&M University System, College Station, TX.

Elliott, M. 1994. Preventative chemical control of blue-green algae on bermudagrass putting greens. *In*: Turfgrass Res. in Florida, May 1994. University of Florida, Gainesville, FL.

Elliott, M. 1995. Preventative chemical control of blue-green algae on bermudagrass putting greens. *In*: Turfgrass Res. in Florida, May 1995. University of Florida, Gainesville, FL.

Koski, A.J., and S.J. Keeley. 1992. Evaluation of isolite as a turfgrass soil amendment. p. 172. *In*: Agronomy Abstracts. ASA, Madison, WI.

Maddox, V.L., J.V. Krans, and M.J. Sullivan. 1997. Survey of algal and cyanobacterial species on golf putting greens in Mississippi, USA. International Turfgrass Soc. Res. J. 8:495-505.

Pease, D.R., and R. Luepke. 1995. Giving greens a second chance. Golf Course Management. 63(7):44-48.

Ralston, D.S., and W.H. Daniel. 1973. Effect of porous rootzone materials underlined with plastic on the growth of creeping bentgrass (*Agrostis palustris* Huds.) Agron. J. 65(2):229-232.

Raven, P.H., R.F. Evert, and H. Curtis. 1981. The classification of living things. *In*: Biology of plants. 3rd ed. Worth Publishers, Inc., New York, NY.

SAS Institute. 1988a. SAS/STAT user's guide. version 6.03. SAS Inst., Cary, NC.

SAS Institute. 1988b. SAS procedure guide. version 6.03. SAS Inst., Cary, NC.

Soika, M.D., and P.L. Sanders. 1991. Evaluation of fungicides for control of dollar spot, brown patch, and associated algal proliferation on creeping bentgrass. p. 29-30. *In*: Turfgrass Res. Results 1990/1991. The Pennsylvania State University, College Park, PA.

Vargas, J.M. Jr., R. Detweiler, S. Beiber, M. Hendricks, and V. Sheridan. 1986. Turfgrass disease management report - 1984-1985: Dollar spot/summer patch fairway study - 1985. p. 70-72. *In*: Proceedings of the 56th Annual Michigan Turfgrass Conf. Vol. 15; 13-15 January.

Waddington, D.V. 1992. Soils, soil mixtures, and soil amendments. p. 331-383. *In*: Turfgrass. ASA, Madison, WI.

Acknowledgments

Appreciation is expressed to Golf Ventures of Lakeland, Florida, for partial funding and materials used in this research. Thanks also to Mid-South Sweeper of Memphis, Tennessee, for the use of the Ryan GA-30 coring machine.

Table 1. Analysis of variance for cyanobacterial numbers on a bermudagrass green showing sources of variation, degrees of freedom (df), mean squares (MS), and F values across 1995 and 1996.

Sources	DF	MS x 10^{10}	*F* Value
Replication	2	37.3947	17.64
Year	1	16.3182	7.70
Replication*Year (E_a)	2	2.1201	0.57
Coring	1	13.7894	2.11
Year*Coring	1	35.9598	5.51
Year*Coring*Replication (E_b)	4	6.5286	1.72
Treatment	3	75.9939	10.46[1]
Treatment*Coring	3	4.4987	0.62
Year*Treatment	3	15.6413	2.15
Year*Treatment*Coring	3	3.0052	0.41
Year*Treatment*Coring*Replication (E_c)	24	7.2677	1.92[2]
Week	5	35.2221	9.31[1]
Week*Coring	5	1.9077	0.50
Week*Treatment	15	12.9297	3.42[1]
Week*Treatment*Coring	15	3.5710	0.94
Year*Week	5	65.4561	17.29[1]
Year*Week*Coring	5	3.5240	0.93
Year*Week*Treatment	15	10.4476	2.76[1]
Year*Week*Treatment*Coring	15	4.3237	1.14
Error (E_d)	160	3.7852	
Corrected Total	287		

[1]Significant at P≤ 0.001 level.
[2]Significant at P≤ 0.01 level.

Table 2. Analysis of variance for cyanobacterial numbers on a bermudagrass green showing sources of variation, degrees of freedom (df), mean squares (MS), and F values within 1995 and 1996.

Sources	DF	MS x 10^{10}	*F* Value
Within Year 1995			
Replication	2	11.7173	1.01
Coring	1	47.1426	4.06
Replication*Coring (E_a)	2	11.6216	2.93
Treatment	3	74.1455	8.54[1]
Treatment*Coring	3	0.5938	0.07
Treatment*Coring*Replication (E_b)	12	8.6867	2.19[2]
Week	5	22.7959	5.74[3]
Week*Coring	5	3.1281	0.79
Week*Treatment	15	8.7318	2.20[2]
Week*Treatment*Coring	15	1.9583	0.49
Error (E_c)	80	3.9705	
Corrected Total	143		
Within Year 1996			
Replication	2	27.7975	19.36[2]
Coring	1	2.6066	1.82
Replication*Coring (E_a)	2	1.4357	0.40
Treatment	3	17.4897	2.99
Treatment*Coring	3	6.9101	1.18
Treatment*Coring*Replication (E_b)	12	5.8488	1.62
Week	5	77.8823	21.63[3]
Week*Coring	5	2.3037	0.64

Week*Treatment	15	14.6454	4.07[3]
Week*Treatment*Coring	15	5.9363	1.65
Error (E_c)	80	3.5999	
Corrected Total	143		

[1]Significant at $P \leq 0.01$ level.
[2]Significant at $P \leq 0.05$ level.
[3]Significant at $P \leq 0.001$ level.

Table 3. Pearson correlation coefficients between algal numbers, cyanobacterial numbers, percent turf cover, and algal/cyanobacterial visual ratings on a bermudagrass green during a 10-week study in 1995 and 1996 showing Pearson correlation coefficients/probabilities.

Dependent variables	Algal numbers		Cyanobacterial numbers		Percent turf cover	
	1995	1996	1995	1996	1995	1996
Cyanobacterial numbers	0.26818 0.0014	-0.30973 0.0002				
Percent turf cover	-0.21208 0.0122	0.26199 0.0015	-0.10225 0.2226	-0.43228 0.0001		
Visual Ratings	0.15157 0.0749	-0.03402 0.6846	0.17869 0.0321	0.27878 0.0001	-0.93132 0.0001	-0.38289 0.0001

Table 4. Cyanobacterial numeric response to biweekly applications of chlorothalonil, diatomaceous earth (DE) plus chlorothalonil, and DE on a bermudagrass putting green during a 10-week study in 1995.

Treatment	Cyanobacteria numbers at 0-10 weeks after initiation [1]						
	0	2	4	6	8	10	LSD[2]
Check	74.87	70.25	70.25	100.77	121.71	94.03	31.849
Chlorothalonil[3]	84.45	58.19	54.64	60.32	75.93	53.93	20.231
DE + chlorothalonil[4]	80.90	51.45	54.99	55.35	59.61	43.29	19.422
DE[5]	74.51	55.35	49.32	60.32	59.97	57.48	N.S.
LSD[2]	N.S.	N.S.	N.S.	17.026	27.802	21.003	

[1]Number of cyanobacteria (x 10,000) per square centimeter.
[2]Significant at $P \leq 0.05$; N.S. = not significant.
[3]Chlorothalonil applied at 1.44 grams ai per square meter.

[4]DE applied at 244 kilograms per square meter, plus chlorothalonil at 1.44 grams ai per square meter.

[5]DE applied at 244 kilograms per square meter.

Table 5. Cyanobacterial numeric response to biweekly applications of chlorothalonil, diatomaceous earth (DE) plus chlorothalonil, and DE on a bermudagrass putting green during a 10-week study in 1996.

Treatment	Cyanobacteria numbers at 0-10 weeks after initiation [1]						
	0	2	4	6	8	10	LSD[2]
Check	83.74	86.57	113.19	84.10	45.42	67.06	23.507
Chlorothalonil[3]	89.06	88.71	73.45	54.29	70.97	80.90	N.S
DE + chlorothalonil[4]	96.87	114.97	63.87	45.06	35.13	52.87	20.270
DE[5]	85.51	89.42	67.06	57.48	46.48	44.00	21.672
LSD[2]	N.S.	N.S.	26.164	21.844	N.S.	24.796	

[1]Number of cyanobacteria (x 10,000) per square centimeter.

[2]Significant at $P \leq 0.05$; N.S. = not significant.

[3]Chlorothalonil applied at 1.44 grams ai per square meter.

[4]DE applied at 244 kilograms per square meter, plus chlorothalonil at 1.44 grams ai per square meter.

[5]DE applied at 244 kilograms per square meter.

Table 6. Algal/cyanobacterial visual ratings recorded from plots treated with biweekly applications of chlorothalonil, diatomaceous earth (DE) plus chlorothalonil, and DE on a bermudagrass putting green during a 10-week study in 1996.

Treatment	Visual ratings at 0-10 weeks after initiation [1]						
	0	2	4	6	8	10	LSD[2]
Check	4.0	4.0	4.3	4.3	3.0	3.7	0.75
Chlorothalonil[3]	4.0	2.7	3.2	2.7	4.3	4.3	0.87
DE + chlorothalonil[4]	4.0	2.0	2.2	2.0	1.3	2.3	0.48
DE[5]	3.8	2.7	2.3	3.3	3.3	3.0	0.59
LSD[2]	N.S.	0.55	0.63	0.47	1.26	0.70	

[1] Visual ratings range from 1 (no visible algae/cyanobacteria) to 6 (total surface coverage) of algae/cyanobacteria.

[2]Significant at $P \leq 0.05$; N.S. = not significant.

[3]Chlorothalonil applied at 1.44 grams ai per square meter.

[4]DE applied at 244 kilograms per square meter, plus chlorothalonil at 1.44 grams ai per square meter.

[5]DE applied at 244 kilograms per square meter.

Table 7. Turf color ratings for bermudagrass treated with biweekly applications of applications of chlorothalonil, diatomaceous earth (DE) plus chlorothalonil, and DE during 10-week studies in 1995 and 1996.

Treatment	Color ratings at 2-14 weeks after initiation [1]								
	1995[2]		1996						
	8	10	2	4	6	8	10	12	14
Check	7.8	7.8	6.5	6.8	6.7	6.5	7.3	6.7	6.8
Chlorothalonil[3]	7.0	7.1	6.5	7.0	6.0	5.3	5.3	6.2	6.5
DE + chlorothalonil[4]	7.7	7.4	6.8	7.2	6.0	6.0	7.0	7.2	7.2
DE[5]	8.0	7.8	6.7	7.3	7.0	7.3	8.0	7.5	7.7
LSD[6]	0.47	0.55	N.S.	N.S.	0.58	0.83	0.67	0.76	1.21

[1] Color rating based on a scale from 1 = yellow to 9 = dark green.

[2] Weeks during study prior to those shown represent weeks in which no color differences were observed.

[3] Chlorothalonil applied at 1.44 grams ai per square meter.

[4] DE applied at 244 kilograms per square meter, plus chlorothalonil at 1.44 grams ai per square meter.

[5]DE applied at 244 kilograms per square meter.

[6] Significant at $P \leq 0.05$; N.S. = not significant.