

CHAPTER 2

TEMPORAL SHADE ON CREEPING BENTGRASS TURF

ABSTRACT

Shade is generally detrimental to turfgrass plants. Creeping bentgrass (*Agrostis palustris* Huds.) is a relatively shade-tolerant species but declines rapidly when exposed to low light conditions and short mowing heights. Many turfgrass researchers believe that creeping bentgrass turf exposed to shaded conditions during morning hours declines more readily than similar turf exposed to afternoon shade. This hypothesis has never been scientifically tested. The objectives of this study were to compare the quality and physiological responses of creeping bentgrass turf exposed to morning shade with creeping bentgrass turf exposed to afternoon shade and to evaluate responses of the same turf exposed to 100% light reduction shade cloth compared to 80% light reduction shade cloth during the same period. Semi-permanent shade structures were placed on a creeping bentgrass range maintained at a 6.35 mm (1/4 in.) mowing

height. Structures were aligned to provide 6 h of morning shade or 6 h of afternoon shade during summer solstice. Each structure was covered with either 80% shade cloth or 100% shade cloth and each treatment was replicated three times. Control treatments of full sun and perpetual shade were also included. Treated turf was evaluated monthly for color, density, root mass, pigment concentrations and total nonstructural carbohydrates. Data were analyzed using analysis of variance and means separated by least significant difference and orthogonal contrasts. Results for the months of August, September, and October, 1996 and April through October, 1997 indicated no significant variation among plots receiving morning shade and plots receiving afternoon shade or plots receiving 80% shade and 100% shade regardless of the response tested. Results of this study may enable golf course superintendents and other turfgrass managers to improve turfgrass health in shaded areas through selective tree removal while maintaining the integrity and beauty of the site.

INTRODUCTION

Shade is generally considered detrimental to turfgrass growth and development. Reduced levels of photosynthetic irradiance result in thinner, more delicate leaf blades (Dudeck and Peacock 1992) prone to mechanical injury and disease infection. Under shaded conditions, carbohydrate availability is limited due to decreased photosynthetic production and results in reduced root growth, reduced tillering, and poor shoot density. Trees and other plants as well as structures providing shade also affect air circulation increasing relative humidity and causing leaf surfaces to remain wet with dew for many hours. These wet leaf surfaces combined with reduced evapotranspiration create a microclimate conducive for disease development. Physiological turfgrass features such as pigment concentrations (Possingham 1980; Wilkinson and Beard 1975) and carbohydrate reserve (Voskresenskaya 1972; Burton, et al. 1959) may be affected by shade stress. The ratio of chlorophyll a to chlorophyll b has been used to indicate shade stress in many plants (Boardman 1977). In shade, this ratio decreases. The conversion of violaxanthin to zeaxanthin through antheraxanthin is believed to be a quenching mechanism for excess excitation

energy common during high light conditions (Demmig-Adams, et al. 1990). This conversion and the reverse process occurs very quickly so high levels of zeaxanthin are not likely to be present in low light. In addition to this conversion, levels of the xanthophyll pool increase in plants exposed to full sun in comparison to plants exposed to shade (Gilmore and Yamamoto 1991; Thayer and Bjorkman 1990). If pigment samples are collected after dark, high concentrations of zeaxanthin and antheraxanthin are unlikely, but the concentration of violaxanthin may be indicative of the level of solar radiation to which the plant is normally exposed.

Creeping bentgrass (*Agrostis palustris* Huds.), a turfgrass commonly used on golf course fairways and greens, has good shade tolerance in comparison to most grasses (Turgeon, 1991). When used for golf course playing surfaces, creeping bentgrass is rarely mowed higher than 1.26 cm (1/2 in). These low mowing heights reduce leaf surface area and limit photosynthetic ability. Low light conditions aggravate this situation and may cause a decline in shoot density detrimental to the uniformity of the playing surface. Field observations suggest that playing surfaces subjected to shade during the morning hours decline more readily than those subjected to shade in the afternoon. These observations deserve consideration, but have never been scientifically tested. Turfgrass managers consistently meet resistance from players when suggesting that trees be removed or canopies be thinned to improve air circulation and

allow light to reach playing surfaces. It may be possible to improve turf health by removing trees or by thinning tree canopies on only one side of the playing surface, minimizing both player resistance and expense. The objective of this study was to compare the quality and physiological characteristics of creeping bentgrass turf exposed to shade in the morning with creeping bentgrass turf exposed to shade in the afternoon. A second objective was to compare the quality and physiological characteristics of creeping bentgrass turf exposed to 80% light reduction cloth during a portion of the day with creeping bentgrass turf exposed to 100% light reduction cloth during an equal portion of the day.

MATERIALS AND METHODS

A 'Penncross' creeping bentgrass range, 6.1 by 73.2 m (20 x 240 ft.), was selected at The Ohio State University Turfgrass Research Center and divided into 1.2 m (4 ft) sections separated by 3.0 m (10 ft) sections lengthwise. Each 1.2 m section was randomly selected to receive one of six treatments, 1) full sun, 2) perpetual shade, 3) 100% AM shade, 4) 80% AM shade, 5) 100% PM shade, or 6) 80% PM shade. Each treatment was replicated three times. The range was mowed three times weekly (Mon., Wed., Fri.) at 6.35 mm (1/4 in.) and irrigated daily just before sunrise during dry periods. Fertilizer, 24% nitrogen (predominately isobutlydiurea), 4% phosphorus (P_2O_5), and 12% potassium (K_2O) was applied monthly at 24.4 kg N ha⁻¹ (0.5 lb. N 1000 sq. ft.⁻¹) during the spring and fall months and 12.2 kg N ha⁻¹ (0.25 lb. N 1000 sq. ft.⁻¹) during the summer months. Chlorothalonil (tretachloroisophthalonitrile) was applied preventatively every three weeks for dollar spot and brown patch control during peak infection periods and metalaxyl [N-(2,6-dimethylphenyl)-N-(methoxyacetyl) alanine methyl ether] for Pythium blight during the summer months.

Semi-permanent shade structures were constructed of polyvinyl chloride pipe and covered with 100% knitted shade cloth or 80% knitted shade cloth (Chicopee, Gainesville, GA) according to treatment (Figure 1.1). Shade structures were constructed vertically to allow rainfall and irrigation to reach the plots. The structures were mounted in sleeves buried in the soil to allow removal for mowing, fertilization, and chemical applications. Morning shade structures were oriented facing 45° south of a line parallel to the first morning shadow during summer solstice. The area behind each structure that was shaded for the first 6 h of the day during mid-summer was selected as the treatment plot and resulted in an area measuring 0.39 m^2 (4.17 ft^2). Afternoon shade structures were oriented 45° south of the final shadow of the day and plots selected as before. Each of these temporal structures provided shade for approximately 40% of each day and full sun for approximately 40% of each day with a transition period between sun and shade accounting for approximately 20% of each day. Perpetual shade structures were covered with 80% shade cloth and provided shade continuously and control plots were randomly identified to receive full sun. Shade structures were placed on the turf on August 1, 1996 and removed November 1, 1996 to correspond with deciduous leaf fall. Structures were replaced at the site on June 1, 1997 and remained through October 1, 1997. A model LI-1800 spectroradiometer (LiCor, Lincoln, NE) was used to assess spectral quality and light intensity in the shade of each structure. Scans were

made 4.5 h before solar noon and 4.5 h after solar noon on July 15, July 29, and August 26 under variable skies. Scans were also made on June 5 (PM) and on July 2 (AM) for a total of eight replications.

Turf canopy temperatures were recorded under clear skies for shaded treatments and for full sun treatments on June 6, July 15, and July 29. Temperatures were measured using an ST27 turf monitor infrared detector (Standard Oil Engineering Materials) 4.5 h before solar noon and 4.5 h after solar noon each day under clear skies.

Each plot was visually rated for color (see Appendix C) and shoot density on the first of each month. Color was rated on a 1 through 9 scale (1 = brown, 5 = yellow-green, and 9 = blue-green). Shoot density was rated as a percentage of potential density. Plots were also measured quantitatively on the first of each month for pigment concentrations in the leaf blades and total nonstructural carbohydrates (TNC) in the leaves, stolons, and roots combined (see Appendix D). A single sample was collected from each plot using a 2.54 cm (1.00 in.) diameter soil probe and taken before sunrise to achieve consistency among pigment concentrations and metabolism of carbohydrates.

In 1996, chlorophyll concentrations were measured using a Cary 3E spectrophotometer and Varian software (Varian Instruments, Palo Alto, CA) to measure light conductance of samples ground in 80% acetone at 663 nm for chlorophyll a and 645 nm for chlorophyll b. In 1997, high performance liquid

chromatography (HPLC) was used for this purpose because it offered the opportunity to assess the xanthophylls and chlorophylls simultaneously. The HPLC determinations were consistent with Gilmore and Yamamoto (1991). A loosely packed, non-encapped C18, spherisorb ODS-1 column (Alltech, Deerfield, IL) was preceded by a ODS-1 guard column (Alltech, Deerfield, IL) for pigment separation. Sample extract was loaded at 20 μ l per sample into a SpectroSYSTEM autosampler (Thermal Separation Products, Riviera Beach, FL) with flow rate adjusted to 2.0 ml per min. The initial solvent used for separation was a mixture of 86.8% acetonitrile, 9.6% methanol, and 3.6% 0.1 M Tris-HCl buffer (pH 8.0) for 4.0 min followed by a gradient to 20.0% hexane and 80.0% methanol for 2.5 min. The program was completed with the acetonitrile, methanol, tris mixture for a total run time of 18.0 min. Results were compared using peak heights for each pigment tested. Area measurement was deemed unacceptable because peak fusion occurred in many cases near the baseline and because internal standards were not tested as a component of each sample, there was no attempt to estimate concentrations in comparison to leaf tissue mass or area. Chlorophyll a and chlorophyll b standards were tested at the beginning, mid-point, and end of each monthly series of samples constituting a single run. Standards for α -carotene and β -carotene were also tested but standards for the xanthophylls were not available. Extracts were measured spectrophotometrically from 400 to 700 nm wavelength and for the first

derivative of that spectra to determine the presence of specific xanthophylls. Once wavelengths for peak absorbance were determined for each xanthophyll present, the pigments were identified using published data (Lichtenthaler 1987). By comparing the pigments present and their HPLC retention times with those of Gilmore and Yamamoto (1991) and Thayer and Bjorkman (1990), neoxanthin, violaxanthin, and lutein were identified. Collections for pigment analysis and carbohydrate analysis were made prior to sunrise to maintain consistency.

Carbohydrate concentrations were assessed in a modified Weinmann (1947) manner consistent with Smith (1981) except that a mixture of α -amylase (Sigma no. A-2643) and amyloglucosidase (Sigma no. A-7420) was substituted for Mylase 100 enzyme (see Appendix D). Samples were freeze-dried, processed in a cyclone mill through a 1.0 mm mesh screen, boiled for 5 min in double distilled demineralized water and incubated in enzyme solution for 24 h at 45 C to degrade starch to glucose. Solutions were then filtered through Whatman no. 1 paper, proteins precipitated using 10% (w/v) neutral lead acetate, and fructosans hydrolyzed in 0.01 N sulfuric acid. Total nonstructural carbohydrate (TNC) was determined by titration with 0.0002 N sodium thiosulfate using gelatinized starch as an indicator and calculated by comparing sample solutions with blank titrations. Results were recorded in μmol sugar per mg plant tissue.

Root mass was measured prior to TNC analysis using the same 2.54 cm samples used to determine TNC. The length of each sample was trimmed to 4.0 cm below the thatch layer, all soil removed, and the sample freeze dried. Root mass was determined using a Mettler balance and recorded in mg.

The experiment was designed as a randomized complete block using time (month of sampling) as a blocking criterion. Data were analyzed using analysis of variance and means separated by least significant difference. Contrasts were used to evaluate variability between morning and afternoon shade and between 50% shade and 100% shade. Variation was considered significant if the probability of a type I error was less than 0.05%.

RESULTS AND DISCUSSION

Under vertical shade structures covered with 100% shade cloth the average photosynthetic photon flux density (PPFD) was 27% of full sun and under structures covered with 80% shade cloth the average was 35% of full sun. PPFD under the perpetual shade structures which were covered on the top and two sides averaged 20% of full sun. Vertical shade structures allowed more diffuse and reflected light to enter the treatment area accounting for the variation in irradiance. Canopy temperatures in morning shade averaged 2.9°C cooler than air temperature and those in afternoon shade averaged 6.4°C cooler than air temperature. Canopy temperatures in full sun averaged 1.1°C warmer than air temperature in the morning and 2.8°C cooler than air temperature in the afternoon. The average morning air temperature was 21.1°C and the average afternoon air temperature was 25.8°C. Although canopy temperature in relation to air temperature was significantly greater in the morning than in the afternoon, the relationship between canopy temperatures in full sun and shade did not change during the day. Canopy temperature in shade in the morning was 10.1% cooler than canopy temperature in full sun and 9.0% cooler than full sun in the

afternoon. Canopy temperature, therefore, was not considered a component of temporal shade stress (AM stress versus PM stress).

No color variation or turf density variation occurred among plots under 100% and 80% light reduction cloth during the study. Perpetual shade caused a significant decline in both color (8.1 in full sun to 4.7 in perpetual shade) and density (94.5% in full sun to 64.2% in perpetual shade) compared to all other treatments and both morning and afternoon shaded plots (average color = 7.1) displayed a decline in color compared to full sun (Table 2.1). No variation in turf color or turf density was observed between morning and afternoon shaded plots.

Root mass was significantly less in perpetual shade (15.2 mg) than either morning shade (average = 24.9 mg), afternoon shade (average = 25.4 mg), or full sun (22.5 mg)(Table 2.2). No significant variation was observed among other treatments. Plots treated with 100% shade cloth (average = 25.7 mg) did not differ from those treated with 80% shade cloth (average = 24.6 mg) and root mass in morning shade did not differ from root mass in afternoon shade.

Total chlorophyll concentration was significantly lower in perpetual shade in 1996 (14.9 $\mu\text{g chl / mg fw}$) than all treatments except 100% morning shade (18.2 $\mu\text{g chl / mg fw}$)(Table 2.2). Other treatments did not differ and no variation was observed for chlorophyll a / chlorophyll b ratio. Pigment concentrations among treatments did not vary in the spring of 1997 before shade structures were in place. Significant differences existed in 1997 beginning with the July 1

assessment. Chlorophyll a, chlorophyll b, neoxanthin, violaxanthin, and lutein had significant variation throughout the period from July 1 to October 1, but the ratio of chlorophyll a to chlorophyll b was not affected. Each pigment concentration was greatest in full sun and varied significantly between full sun and perpetual shade (Table 2.3). In each case, no variation occurred between morning and afternoon shade treatments or between treatments with 100% and 80% light reduction cloth. These results suggested that the ratio of chlorophyll a to chlorophyll b may not be a reliable indicator of turfgrass shade stress and was not as effective for this purpose as xanthophyll concentrations. The concentration of violaxanthin, for instance, varied with shade duration (Table 1.3). Violaxanthin concentrations are indicative of light stress (Adams III and Demmig-Adams 1992; Gilmore and Yamamoto 1991). Using violaxanthin as an indicator, it was observed that light stress due to accumulation of excess light energy occurred in treatments receiving either full sun or partial full sun and that levels of this pigment varied with the amount of full sun received. Violaxanthin levels were greatest in full sun (17758 mV; 100%) followed by temporal (AM or PM) shade [15348 (86%) to 14542 mV (82%)] and least in perpetual shade (9951 mV; 56%). Other pigment concentrations did not provide this level of detection. These results suggested that violaxanthin content could be used as a direct indicator of light stress or possibly as an inverse detector of shade stress.

No significant variation occurred among treatments in relation to TNC response (Table 2.2). Density and root mass were significantly lower in perpetual shade, suggesting little growth or development, while full sun turf was dense and had a strong root system. These results suggested that turf in perpetual shade conserved carbohydrates by limiting growth and turf in full sun consumed carbohydrates through aggressive growth. These results also suggested that cellular tissues sequestered carbohydrates at consistent concentrations regardless of the solar environment and that plant tissue mass alone may be a better indicator of shade stress than carbohydrate quantity compared to tissue mass. It is interesting to note that perpetual shade had the highest average TNC content and full sun the lowest.

This study was designed to evaluate turfgrass growth under restricted light intensities. The shade environment, however, is a combination of many factors. Restricted air movement and root competition are factors that may influence turfgrass growth in shade. The temporal shade structures used were upright and single sided causing little disruption of air movement. Trees were not present, consequently no root competition occurred. This study demonstrated that no variation occurs between turfgrass growth in morning shade and afternoon shade providing air movement is adequate and tree roots are not present. It also demonstrated that turf receiving sunlight for only 40% of the day maintains color, density, and tissue mass even when shaded at 27% of full sun.

These results indicated that it is neither the intensity of shade nor the temporal period of shade but the duration of shade which is most destructive to turfgrass growth and development. By studying each of these components (light intensity, restricted air movement, and root competition) individually, it may be possible to provide turf managers with adequate information for selective tree trimming rather than indiscriminate tree removal. Defining the relationship between trees and turfgrass encourages the use of trees in the landscape while maintaining a healthy environment for turfgrass growth.

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<u>Treatment</u>	<u>Root</u>	<u>Treatment</u>	<u>TNC</u>	<u>Treatment</u>	<u>Chl</u>
100% PM	27.5 a	Perpetual	83.1 a	80% AM	20.1 a
80% AM	25.9 a	100% PM	76.5 a	80% PM	19.7 a
100% AM	23.8 a	50% AM	76.1 a	100% PM	18.7 a
80% PM	23.2 a	50% PM	71.5 a	Full Sun	18.5 a
Full Sun	22.5 a	100% AM	68.6 a	100% AM	18.2 a
Perpetual	15.2 b	Full Sun	67.9 a	Perpetual	14.9 b
LSD = 6.15		P = 0.94		LSD = 3.45	

Table 2.2. Treatment means for root mass (mg dry tissue in a sample 2.54 cm diameter x 4 cm deep), total nonstructural carbohydrates (TNC)(μmol sugar / g dry tissue) in leaves, roots, and stolons combined, and for total chlorophyll (Chl) concentration (μg Chl / g fw) listed as in Table 1.1. Roots were vacuum freeze dried for 48 h before measurements were made. Data were compared monthly throughout the study. TNC was compared from samples collected on Sept. 1, Oct. 1, Nov.1, 1996 and May 1 through Sept. 1, 1997. Chlorophyll Data were accumulated from samples taken on Sept. 1, Oct. 1, and Nov. 1, 1996. Means were computed from data recorded by spectrophotometric scans. The concentration of chlorophyll a was evaluated at 663 nm and the concentration of chlorophyll b was evaluated at 645 nm (Arnon 1949) from pigments extracted in 80% (v/v) acetone.

<u>Treatment</u>	<u>Neo</u>	<u>Treatment</u>	<u>Viola</u>	<u>Treatment</u>	<u>Lutein</u>
Full Sun	7857 a	Full Sun	17758 a	Full Sun	21064 a
100% AM	7393 ab	100% AM	15348 b	80% AM	19973 a
80% AM	7155 ab	100% PM	14963 b	80% PM	19429 a
100% PM	6869 b	80% PM	14679 b	100% PM	18814 a
80% PM	6808 b	80% AM	14542 b	100% AM	17901 a
Perpetual	5455 b	Perpetual	9951 c	Perpetual	13993 b
	LSD = 890.8		LSD = 1,978.3		LSD = 3,306.3
<u>Treatment</u>	<u>Chl a</u>	<u>Treatment</u>	<u>Chl b</u>	<u>Treatment</u>	<u>Chl a/b</u>
Full Sun	201725 a	Full Sun	49485 a	Perpetual	5.96 a
80% AM	156494 b	80% AM	36504 ab	50% PM	4.71 a
100% PM	152734 bc	100% PM	35739 ab	100% AM	4.54 a
100% AM	150506 bc	100% AM	34488 b	Full Sun	4.34 a
80% PM	144974 bc	80% PM	32937 b	100% PM	4.31 a
Perpetual	109768 c	Perpetual	24949 b	50% AM	4.31 a
	LSD = 45,072.5		LSD = 14,213.7		P = 0.56

Table 2.3. Means for pigment concentrations listed as in Table 1.1. Means were computed from peak heights (mV) determined by high performance liquid chromatography for treatment samples collected on July 1, Aug. 1, Sept. 1, and Oct. 1, 1997. Peaks for neoxanthin (Neo), violaxanthin (Viola), lutein, chlorophyll a (Chl a), chlorophyll b (Chl b), and chlorophyll a divided by chlorophyll b (Chl a/b) were resolved for treatments of full sun, 100% AM shade, 80% AM shade, 100% PM shade, 80% PM shade and perpetual shade. Letters following means indicate significance (P = 0.05).

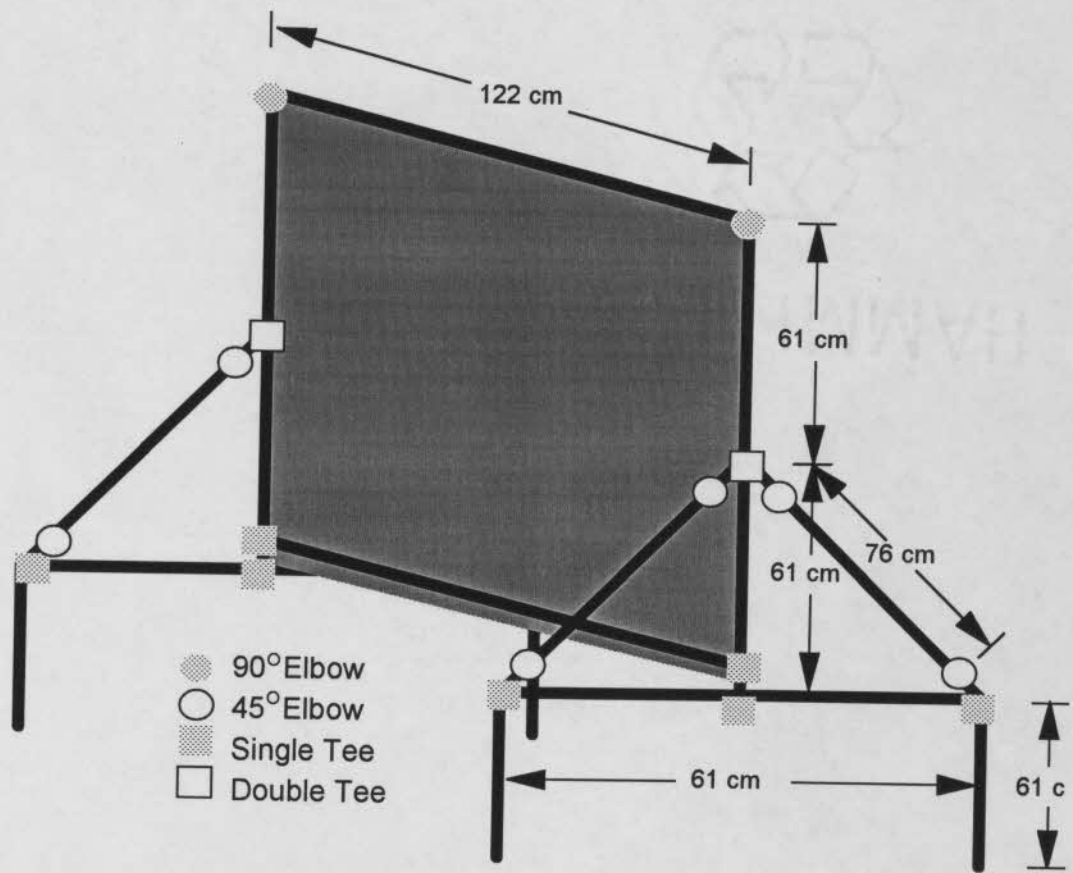


Figure 2.1. Semi-permanent temporal shade structure constructed of 38 mm (1.5 inch) diameter polyvinyl chloride (PVC) pipe. Labeled symbols represent individual fittings used in construction. Legs are slid into 51 mm (2.0 in) diameter PVC sleeves buried in the soil allowing removal of the structure for turf maintenance.