Evaluating St. Augustinegrass (Stenotaphrum Secundatum (Walt.) Kuntze) Cultivars To Reduced Light Environments

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Research Article

Open Access &

Peer-Reviewed Article

DOI:10.14302/issn.2639-3166.jar-23-4606

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Keywords:

Chlorophyll; Photosynthetic Photon Flux (PPF); Shade; Transition Zone; Turfgrass; Zoysiagrass.

Received: June 01, 2023

Accepted: July 03, 2023

Published: July 08, 2023

Academic Editor:

Abubaker Mohan Lal, Assistant Professor, Irrigation and Drainage Engineering department, College of Technology, G B Pant University of Agriculture and Technology, Pantnagar, India.

Citation:

ALambert B. McCarty, Nathaniel J. Gambrell (2023). Evaluating St. Augustinegrass (Stenotaphrum Secundatum (Walt.) Kuntze) Cultivars To Reduced Light Environments. Journal of Agronomy Research - 5(2):01-09 https://doi.org/10.14302/issn.2639-3166.jar-23-4606

Abstract

St. Augustinegrass [Stenotaphrum secundatum (Walt.) Kuntze] generally has poor cold tolerance yet good to excellent shade tolerance. As mostly hot summers follow cold winters in USDA Hardiness Zone 7, severely damaging tall fescue [Lolium arundinaceum (Schreb.) Darbysh.] and centipedegrass [Eremochloa ophiuroides (Munro) Hack.], a St. Augustinegrass cultivar cold tolerant enough to be grown for shady lawns would greatly benefit home owners, recreational sites, and sod growers in the “transition zone.” Eight St. Augustinegrass samples were selected, including industry standards ‘Raleigh’ and ‘Palmetto’, plus ‘Palisades’ zoysiagrass (Zoysia japonica Steud.) for further testing from an established germplasm collection of material collected from lawns grown in USDA Hardiness Zone 7. Overall, based on 8-week greenhouse studies, the experimental lines had similar shade tolerance compared to commercial standards ‘Raleigh’ ‘Palmetto’ and ‘Palisades’ zoysiagrass. Field studies may be warranted to validate greenhouse studies to help further evaluate shade tolerance of experimental and commercial lines. Information generated supports the use of certain St. Augustinegrass selection in a wider environmental conditions such as reduced light environments (RLE).

Introduction

Stenotaphrum is a perennial genus comprising of eight species and is widely distributed in the Pacific Islands, Africa, and the Americas (1). St. Augustinegrass [Stenotaphrum secundatum (Walt.) Kuntze] is considered one of the most shade-tolerant warm-season turfgrass species (2, 3), and is used for lawns (4), soil and water conservation (1) and as a shade tolerant forage (5). However, it is considered one of the poorest warm-season grasses in terms of cold tolerance though recent work has identified selections which can tolerate -6°C (6). Based on molecular markers, its accessions are highly diverse, providing a basis for its multiple uses, and can be divided into three classes based on seven phenotypic traits (1).Morphological differences also are sufficient to distinguish between most cultivars (7). Propagation is primarily vegetative by plugs or sod as few viable seedheads are formed. It has strong, thick stolons, course leaf texture, and produces a turf of medium density. The maintenance requirement is medium, though the grass has a vigorous growth rate, moderate fertilization is necessary. St. Augustinegrass is maintained at a height of 3.8 to 7.6 cm (1.5 to 3 inches) with either a reel or rotary mower (8).

Previous research has identified typical turf responses to shaded environments (9). Morphological characteristics include longer leaf length (10), longer internode lengths (11, 12), reduced clipping weights (10, 13), and increased leaf area (2, 11). Reduced tillering and stand density are also typical responses to shaded conditions (2, 12, 14). Physiological changes generally include greater chlorophyll concentration (2, 12), although Peacock and Dudeck (11) noted shade did not affect the chlorophyll content of certain St. Augustinegrass cultivars. They also saw differences in shoot growth between cultivars under shaded conditions, which may have contributed to lower chlorophyll content. Barrios et al. (13) noted turfgrass quality generally declined as shade increased, particularly under severe RLEs.

Only limited published information exists pertaining to comparative shade tolerance of St. Augustinegrass (15). In recent years, newer cultivars with reportedly improved shade tolerance such as 'Amerishade' and 'Captiva' have been developed (6, 16, 17); however, data on their comparative shade tolerance in relation to other commercially available cultivars are lacking as are their cold tolerance (15). Trenholm and Nagata (9) and Cai (18) reported best shade tolerance in dwarf cultivars of St. Augustinegrass and optimal turf performance at 30% shade compared with 0%, 50%, or 70% in all cultivars.

Dudeck and Peacock (19) stated shade adaptation of a turfgrass ground cover is influenced by a complex of microclimatical, pathological, and physiological responses. Primary factors involve: reduced irradiance; tree root competition for nutrients and water; microclimate favoring disease activity; succulent grass tissue; and, reductions in shoot density, root growth, and carbohydrate reserves (2, 10, 14, 19, 20).

Plants which adapt to shade environments do so by a combination of physiological or morphological adaptations (21). Plants capable of shade adaptation develop a higher photochemical efficiency, which is expressed by a steeper slope in the early phases of their light response curves. Boardman (22), however, concludes no one factor is the primary cause of altered photosynthetic capacity. Wilkinson et al. (10) concluded the photosynthetic respiratory balance is a critical factor in shade adaptation. For a plant to survive, net photosynthesis must exceed respiration (3).

Knowledge of what cultivar might perform best under shade is an important issue for builders, landscape designers, ranchers, and horticulturists (5, 9). Determining and comparing shade limits for currently available cultivars along with new experimental lines is necessary information for turf managers and homeowners.

Materials and Methods

The purpose of this study was to evaluate shade tolerance of a St. Augustinegrass germplasm collection from upstate South Carolina (US), including commercial cultivars 'Raleigh', 'Palmetto' and 'Palisades' zoysiagrass. Comprehensive evaluations of these plant collections could open new opportunities for turf managers and homeowners.

In 2002, a germplasm collection was established with samples from 30 St. Augustinegrass lawns grown in USDA Hardiness Zone 7. These samples, along with commercial standards, 'Raleigh' and 'Palmetto', were established by plugs under natural low light (~50% full sunlight) conditions in Clemson, South Carolina (34°40'14'' N, 82°50'15'' E).

In June of 2012, plugs from the top six performing grasses, along with 'Raleigh' and 'Palmetto', and 'Palisades' zoysiagrass were collected and transplanted into 24 plastic trays (53 x 38 x 8 cm), filled with river sand, using four, 5 cm, plugs per tray. Trays were transported to Clemson University's Greenhouse Facility and grown for 12 months at 25 $\pm$ 10ºC. Once established, shade studies were conducted for further evaluations.

Two 8-week experiments were conducted at Clemson University's Greenhouse Research Complex during 2013. Study 1 was conducted from 7 June 2013 to 2 August 2013. While study 2 was conducted from 18 November 2013 to 6 January 2014. Greenhouse temperatures averaged 31°C/22°C (day/night) for study 1 and 26°C/20°C (day/night) for study 2.

Grass samples were established from 10 cm diameter x 3 cm deep, round cup cutter plugs from previously established trays into 15 cm diameter x 11 cm deep round pots filled with a potting soil medium (Fafard 3B mx, Concord Fafard Inc., Agawam, MA, USA). Pots were fertilized at 25 kg N ha^{-1} on a three week interval with a 1-1-1 complete fertilizer, watered every other day to field capacity, and mowed at 5.5 cm twice weekly until all grasses attained ideal turf quality and density. This length of pre-treatment grow-in period required to reach ideal canopy density was 6 weeks for study one and 10 weeks for study 2. Natural sunlight and daylength were used during the greenhouse establishment phase.

Shade treatment structures were constructed to evaluate the response of experimental and commercial lines of St. Augustinegrass to four levels of a reduced light environment (RLE): 0, 30, 50, and 70%. Two shade structures of each RLE level were constructed with the appropriate shade cloth to obtain these RLEs.

Light reduction of each shade cloth was determined by comparing photosynthetic photon flux (PPF) (µmol m^{-2} s^{-1}) under the shade cloths at soil level to full-irradiance PPF measurements with a LI-28663 quantum light sensor (LiCor, Inc., Lincoln, NE, USA) $[(PPF_{full\ sun} - PPF_{under\ shade\ cloth})/PPF_{full\ sun}] \times 100$.

Reduced light environments were applied continuously using neutral density, poly-fiber black shade cloth (model SC-black30, SC-black50, SC-black70; International Greenhouse Company, Danville, IL, USA) that removed equal amounts of light across the photosynthetically active light spectrum. Individual shade cloth tent frames were 1 × 1 m and constructed with 5.3 cm diameter polyvinyl chloride (PVC) pipes. Shade cloths were attached to PVC frames with zip-ties and pulled taut to maintain shade cloths at a consistent height above the soil surface and maintain consistent surface temperature and air movement among all treatments.

Underneath each shade structure, pots were arranged in a completely randomized design with four replications per treatment (shade) level with nine different grass samples totaling 36 pots per treatment (shade) level. Equal numbers of pots were placed under each shade structure with two shade structures per treatment (shade) level. A 20 cm buffer around the perimeter was used to reduce potential border effects during the study. Pots were re-randomized every two weeks when ratings were taken and mowed to avoid localized environmental conditions.

Photoperiod in the greenhouse was extended to 12 h with 1000-W lamps (300 µmol m^2 s^1 light intensity) located approximately 2 meters above the turf canopy for study two to provide similar photoperiod length as study one. Irrigation was maintained as needed to meet evapotranspiration at the varying shade levels throughout the experiment. At study initiation, pots were trimmed vertically to a height of 5.5 cm as well as laterally back to the original 15 cm diameter pot size.

Morphological ratings of leaf width, leaf length, and internode distance were evaluated every two weeks. The average distance of the two longest leaves from the soil surface to the tip were measured from each pot for length (mm) and measured mid-way up the length of the leaf for width using a ruler. Internode distance was measured using the average of two longest stolons growing to the third internode past the pot edge. The distance between the second and third internode was measured. Daily leaf elongation rate ($mm \cdot d^{-1}$) was calculated by subtracting height of cut from leaf length and divided by number of days since previous mowing. After measurements, pots were trimmed back to original 5.5 cm height.

Visual turf quality and turf density was evaluated every two weeks using a 1 to 9 scale, where 1 = dead turf, 6 = minimally acceptable quality, and 9 = perfect green turf. Clipping weights were quantified monthly (weeks 4 and 8). Pots were trimmed to original 5.5 cm height, clippings collected, dried for 48h at 60°C, then weighed (g). Root weights were collected upon conclusion of studies. Roots were removed from pots, clipped below thatch, washed and sieved to remove any attached soil, dried for 48h at 60°C, then weighed.

For study 2, chlorophyll content was measured monthly (week 4 and 8) using a chlorophyll meter (Field Scout CM 1000; Spectrum Technologies, Inc., Plainfield, IL, USA), which measured ratios of reflected red and far-red light to calculate relative chlorophyll content, or greenness. The output is a unitless index of chlorophyll content on a scale of 0 to 999 (23). Two measurements were taken per pot and averaged. All measurements were taken between 1200 and 1400h with pots removed from shade structures. Measurements were taken with the unit 1m from turf surface.

Data were analyzed using PROC MIXED repeated measures analysis. Means separation procedures were performed by Fisher's protected LSD. All comparisons were based on an $\alpha = 0.05$ significance level and conducted using SAS version 9.3 (SAS Institute Inc., Cary, NC). Final (week 8) data was presented to provide comparison of experimental lines and commercially available cultivars.

Results and Discussion

Visual Ratings

At all RLE's (0, 30, 50, and 70%), differences were not seen among commercial cultivars and experimental lines for final turf quality (Tables 1-4) as all entries maintained acceptable quality levels (>6). Final turf density scores had a similar trend as no differences were found between entries at any RLE. At 70% RLE (heaviest shade), experimental line 'E' and experimental line 'F' numerically had turf density values below acceptable levels but statistically weren't significant. Visually, experimental lines collected from USDA Hardiness Zone 7 performed comparable to current commercially available cultivars 'Palmetto' and 'Raleigh' as well as 'Palisades' zoysiagrass.

Morphological Ratings

0% RLE. All St. Augustinegrass entries had similar leaf widths, between 7.0 and 8.4 mm (Table 1). As expected, all St. Augustinegrass entries were statistically different from the naturally narrower 'Palisades' zoysiagrass leaf width of 3.6 mm. A similar trend was seen for leaf elongation rate. All St. Augustinegrass entries provided a similar elongation rate between 1.3 – 2.7 $mm \cdot d^{-1}$ compared to 4.8 $mm \cdot d^{-1}$ elongation rate of 'Palisades' zoysiagrass. Internode distance for experimental 'A' (4.5 mm) was significantly longer than experimental 'G' (2.1 mm) but similar to all other entries.

30% RLE. All St. Augustinegrass entries had similar leaf widths between 7.6 – 8.6 mm and again was

Table 1. Final (8 week) St. Augustinegrass parameter measurements under no shade [0% reduced light environment (RLE)][1].

No Shade (0% RLE)								
Selection	Turf quality	Turf density	Clipping weight	Root weight	Chlorophyll content	Leaf width	Leaf elongation rate	Internode distance
	(1-9)	(1-9)	(g)	(g)	(0-999)	(mm)	($mm \cdot d^{-1}$)	(cm)
A	6.6	7.4	3.1	9.9	192.8	7.1	1.3	4.5
'Raleigh'	7.1	7.5	2.5	8.6	293.5	7.5	2.1	2.8
C	8.1	8.4	2.4	10.6	337.8	7.4	1.0	2.9
'Palmetto'	7.6	7.4	2.9	10.9	313.8	7.1	2.1	2.7
E	7.3	7.3	2.6	10.1	323.5	7.6	2.7	3.5
F	8.0	7.6	2.5	10.2	384.3	8.4	1.4	2.9
G	8.3	8.6	2.8	10.7	276.8	7.5	1.4	2.1
H	7.3	7.8	2.3	9.1	295.8	7.0	1.4	3.1
'Palisades' zoysiagrass	8.0	8.3	2.4	10.9	188.0	3.6	4.8	2.0
LSD (0.05)	NS	NS	NS	NS	136.27	2.01	1.834	2.375
P-value	0.3457	0.3992	0.1806	0.0666	0.0008	0.0167	0.0372	0.0359

[1]Abbreviations: LSD = least significant difference; NS = not significant (α=0.05).

Table 2. Final (8 week) St. Augustinegrass parameter measurements under light shade [30% reduced light environment (RLE)][1].

30% RLE							
Selection	Turf quality	Turf density	Clipping weight	Root weight	Chlorophyll content	Leaf width	Leaf elongation rate
	(1-9)	(1-9)	(g)	(g)	(0-999)	(mm)	($mm \cdot d^{-1}$)
A	7.0	7.0	1.8	7.3	289.8	8.1	2.7
'Raleigh'	7.0	7.8	2.2	8.5	335.3	8.0	3.8
C	7.8	7.5	2.0	8.8	332.5	7.8	3.2
'Palmetto'	6.8	6.9	1.8	7.4	262.5	8.6	3.5
E	7.1	7.4	2.3	8.6	280.5	7.6	3.8
F	7.3	7.3	1.9	8.0	283.0	7.9	2.3
G	7.6	7.6	1.9	7.8	336.5	8.6	2.9
H	7.1	7.3	1.9	8.1	296.5	8.3	4.0
'Palisades' zoysia	7.5	7.3	2.1	8.6	273.3	3.5	6.0
LSD (0.05)	NS	NS	NS	NS	NS	1.6234	2.5952
P-value	0.1555	0.3531	0.8214	0.3214	0.2927	0.0053	0.0204

[1]Internode distance not measurable due to stolons lacking third internode.

Abbreviations: LSD = least significant difference; NS = not significant (α=0.05).

Table 3. Final (8 week) St. Augustinegrass parameter measurements under moderate shade [50% reduced light environment (RLE)][1].

50% RLE								
Selection	Turf quality	Turf density	Clipping weight	Root weight	Chlorophyll content	Leaf width	Leaf elongation rate	Internode distance
	(1-9)	(1-9)	(g)	(g)	(0-999)	(mm)	($mm \cdot d^{-1}$)	(cm)
A	7.3	7.0	1.6	8.3	281.0	6.8	4.4	-
'Raleigh'	6.8	6.8	1.5	7.4	202.3	8.2	2.9	3.5
C	7.1	7.5	2.0	8.7	240.5	7.4	3.1	3.2
'Palmetto'	6.9	6.9	1.6	7.3	290.3	7.1	3.8	-
E	6.9	7.0	2.1	8.3	313.8	7.9	4.1	-
F	7.5	7.3	1.69	8.8	299.0	7.6	3.3	6.3
G	7.3	7.5	1.4	7.9	230.8	7.8	4.3	2.6
H	7.1	6.9	1.5	7.5	141.3	8.0	4.2	-
'Palisades' zoysia	7.4	7.3	2.2	8.7	332.0	3.4	7.1	-
LSD (0.05)	NS	NS	NS	NS	NS	3.48	NS	2.697
P-value	0.1786	0.4465	0.2251	0.2763	0.2403	0.0002	0.0639	0.049

[1]Internode distance not always measurable due to stolons lacking third internode.
Abbreviations: LSD = least significant difference; NS = not significant (α=0.05).

significantly wider than 'Palisades' zoysiagrass (3.5 mm) (Table 2). All St. Augustinegrass entries provide a similar elongation rate between 2.3 – 4.0 $mm \cdot d^{-1}$. 'Palisades' zoysiagrass had a leaf elongation rate of 6.0 $mm \cdot d^{-1}$, which was different from four experimental ('A', 'C', 'F', and 'G') and one commercial ('Palmetto') St. Augustinegrass entries. The lack of stolons with a third internode past the edge of the pot failed to generate internode distance ratings in the 30% RLE.

50% RLE. All St. Augustinegrass entries had similar leaf widths between 6.8 – 8.2 mm, again, significantly wider than 'Palisades' zoysiagrass (3.4 mm) (Table 3). All entries had similar leaf elongation rates between 2.9 – 7.1 mm. Experimental line 'F' had a longer internode distance (6.3 cm) than experimental lines 'C' (3.2 cm) and 'G' (2.6 cm) as well as commercial cultivar 'Raleigh' (3.5 cm). These four entries were the only entries to produce measurable stolons with a third internode past the pot edge at 50% RLE.

70% RLE. All St. Augustinegrass entries had similar leaf widths between 7.0 – 8.4 mm, again significantly wider than 'Palisades' zoysiagrass (3.4 mm) (Table 4). All entries had similar leaf elongation rates between 4.4 – 7.1 $mm \cdot d^{-1}$. Similar to 30% RLE, insufficient stolon lengths prevented internode distance ratings at 70% RLE.

Overall increased leaf elongation rates from 0% RLE to 70% RLE supports previous research stating shaded environments result in longer leaf lengths (7). Experimental entry 'F''s internode distance increased from 0% RLE to 50% RLE also supports previous research that shaded environments increase internode distances (11). In the field, St. Augustinegrass would generally be mowed with greater

Table 4. Final (8 week) St. Augustinegrass parameter measurements under heavy shade [70% reduced light environment (RLE)][1].

70% RLE							
Selection	**Turf quality**	**Turf density**	**Clipping weight**	**Root weight**	**Chlorophyll content**	**Leaf width**	**Leaf elongation rate**
	(1-9)	(1-9)	(g)	(g)	(0-999)	(mm)	($mm \cdot d^{-1}$)
A	6.4	6.5	1.0	7.6	167.8	7.9	5.4
'Raleigh'	7.0	6.8	1.2	6.0	225.8	7.6	4.6
C	6.6	6.9	1.0	6.6	183.3	8.4	4.6
'Palmetto'	6.9	6.8	1.1	6.7	186.3	7.8	5.3
E	6.3	5.5	0.9	6.7	195.3	7.6	4.4
F	6.8	5.9	1.0	7.0	175.8	7.6	4.7
G	7.6	7.8	1.2	5.6	225.5	7.9	5.0
H	6.5	6.6	1.2	11.0	199.0	7.0	6.4
'Palisades' zoysia	6.9	6.4	1.5	7.3	202.5	3.4	7.1
LSD (0.05)	NS	NS	NS	NS	NS	1.8832	NS
P-value	0.3354	0.0913	0.1541	0.4034	0.9676	0.0011	0.1924

[1]Internode distance not measurable due to stolons lacking third internode.

Abbreviations: LSD = least significant difference; NS = not significant (α=0.05).

frequency and perhaps at a higher height, however, this study was designed to maximize differences to shade responses among entries. A 14-d clipping interval was also used by Trenholm and Nagata (9) in screening St. Augustinegrass cultivars for shade tolerance. It is plausible that a greater clipping frequency could have potentially resulted in somewhat improved quality of plants in this study, as greater frequency of mowing can promote increased tillering (2, 3).

Shade tolerance indicators

Clipping weights, root weights, and chlorophyll content were all measured for indicators of shade tolerance. At 0% RLE (Table 1), clipping weights and root weights were similar for all entries ranging from 2.3 – 3.1 g and 8.6 – 10.9 g, respectively. Five experimental entries ('C', 'E', 'F', 'G', and 'H') and both commercial cultivars ('Raleigh' and 'Palmetto') had similar chlorophyll content readings, measuring from 276.8 – 384.3 chlorophyll content index (CCI). Experimental entry 'A' (192.8) and 'Palisades' zoysiagrass (188.0) had a significantly lower CCI than experimental 'F' (384.3) and experimental 'C' (337.8).

At 30%, 50%, and 70% RLE (Table 2 – 4), clipping weights, root weights, and chlorophyll content were similar for all entries. At 30% RLE, clipping weights ranged from 1.8 – 2.3 g while root weights ranged from 7.3 – 8.8 g. Chlorophyll content ranged from 262.5 – 336.5 CCI. At 50% RLE, clipping weights ranged from 1.4 – 2.2 g, root weights ranged from 7.4 – 8.8 g. Chlorophyll content ranged from

141.3 – 332.0 CCI. At 70% RLE, clipping weights ranged from 0.9 – 1.5 g and root weights ranged from 6.0 – 11.0 g. Chlorophyll content ranged from 167.8 – 225.8 CCI. Among these parameters evaluated, considerable variability existed but experimental lines performed comparable to commercially available cultivars.

Conclusions

In conclusion, based various measurements made on 8-week greenhouse studies, the experimental lines had similar shade tolerance compared to commercial standards 'Raleigh' 'Palmetto' and 'Palisades' zoysiagrass. Field studies may be warranted to validate greenhouse studies to help further evaluate shade tolerance of experimental and commercial lines. Results herein, along with previous research on the cold tolerance of these selections (6), support a much wider potential geographical growing range for certain St. Augustinegrass selections than previously recommended.

Acknowledgements

Technical Contribution No. 7176 of the Clemson University Experiment Station. This material is based upon work supported by the NIFA/USDA, under project number SC-1700607. Dr. Patrick Gerard provided experimental design and statistical analysis assistance.

Abbreviations

CCI, Chlorophyll content index; PPF, photosynthetic photon flux; RLE, reduced light environment; USDA, United States department of agriculture.

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