Final Report
as presented to the HRDC

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Agency: Australian Turfgrass Research Institute
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INTRODUCTION

Maintenance of turf grasses in shaded conditions is a major problem for professional turfgrass managers and home owners alike. Beard (1969) estimated that 20-25% of turfgrass areas are maintained under some degree of shade. He described the major effects of shade on the plant microenvironment as reduced light intensity, restricted wind movement, increased relative humidity, moderation of temperature extremes and increased CO₂ level. He also pointed out that shade can affect light quality (relative transmittance of the light spectrum), for example the "green shade" produced under deciduous trees, where shaded plants are deprived of the photosynthetically active blue, orange and red spectral regions.

Beard (1969) listed the responses of turfgrasses to shade as follows:

- decreased shoot, root, rhizome and stolon growth;
- decreased root:shoot ratio;
- thinner leaves and stems;
- longer internodes;
- reduced tillering and shoot density;
- increased leaf area, and;
- increased tissue moisture content.

It is important to realise that the preceding list comprises broad generalisations. Peacock and Dudeck (1980) found that the physiological and morphological responses of *Stenotaphrum secundatum* (Australia = buffalo grass; U.S.A. = St. Augustine grass) varied between cultivars. Additional plant responses to shade have been recorded, such as stimulated or repressed seedhead formation, dependent on light quality (McVey and Mayer, 1969), altered chlorophyll content and composition (Beard 1973; Peacock and Dudeck, 1980), decreased leaf longevity, net photosynthesis, respiration, and carbohydrate content of stolons (references cited by Winstead and Ward, 1974). The consequence of the combined responses of turfgrass to shade include a general deterioration in plant vigour and reduced resistance to heat, cold, drought, disease and wear stress (Beard, 1969).

Numerous studies have been conducted during the past three decades to identify grass species and varieties which are naturally well adapted to shade.

Of the warm season grasses, it is generally held that *S. secundatum* is one of the most shade tolerant turfgrasses (Peacock and Dudeck, 1980). However, Barrios *et al.* (1986) found that the quality ratings and clipping yields of *S. secundatum* cv.s Floratam and Floratine were significantly reduced under shade. The study by Peacock and Dudeck (1980) illustrated the differences in shade adaptation between *S. secundatum* cultivars, including Floratam and Floratine. Beard *et al.* (1985) irradiated the cultivar Floratam and selected mutants for shade tolerance, among other characteristics. Two lines were developed with improved growth in shade.

Smith and Whiteman (1983) evaluated the shade tolerance of a wide range of warm season grasses under coconut canopies in the Solomon Islands. *S. secundatum* produced the greatest growth rate under heavy shade (20% light transmission). The grasses included broadleaved carpetgrass (*Axonopus compressus*).

The relative shade tolerance of *S. secundatum* in comparison to *Zoysia* species and
Centipedegrass (*Eremochloa ophiuroides*) has varied between studies. Barrios *et al.* (1986) found that the shade quality ratings of *S. secundatum* cv.s Floratine and Floratam were less than those for *E. ophiuroides* cv. Oklawn and *Z. japonica* x *Z. temuifolia* cv. Emerald. The degree of growth reduction under shade was also greatest for *S. secundatum*. In contrast, Wells and Constantin (1983) ranked the quality of Emerald zoysia and centipedegrass in shade above that of *S. secundatum* common and *Z. japonica* cv. Meyer, however they ranked the density of Meyer zoysia much higher than *S. secundatum*. Johnson and Carrow (1987) found that both Emerald and Meyer zoysia grasses provided "good cover" under shade without suffering from winter kill, however *S. secundatum* cv. Raleigh was severely injured by cold.

It is likely that the contrasting shade tolerance rankings of *S. secundatum* cv.s, *Zoysia* spp. and *E. ophiuroides* are due to differences in the shade regimes imposed, together with differences in the species and/or cultivars evaluated. Both *S. secundatum* and *Zoysia* spp. are generally regarded as shade tolerant grasses, however it is important to be aware that broad generalities are unlikely to be accurate.

In much the same manner, there are reported inconsistencies in the relative shade tolerance of *S. secundatum* and *Cynodon* spp. (Australia = couchgrass; U.S.A. = bermuda grass). McBee and Holt (1966) found that the shade tolerance of a Florida *Cynodon* selection 'No-Mow' exceeded that of *S. secundatum* common, however the shade tolerances of both Tifway and 'Q-2' *Cynodon* were poorer. Gaussoin *et al.* (1988) and Coffey and Baltensperger (1989) reported that the natural variation in shade tolerance between *Cynodon* clones indicates potential for selection. These workers found that 5 genotypes including 'No-Mow' were shade tolerant, and that genotypes including Santa Ana and Tifway were extremely intolerant to shade.

Beard (1973) listed the effects of shade upon turfgrass morphology, which included the development of thinner leaves with less weight per unit area. The development of thinner leaves with greater 'specific leaf area' (S.L.A.) (cm² g⁻¹) by shaded turfgrass is both a sensitive indicator of shade tolerance and a practical measure of wear resistance. Grasses which produce a large increase in S.L.A. under shade are more susceptible to mechanical injury of the relatively thin leaves, so from the practical point of view grasses which do not respond markedly in S.L.A. may be regarded as more suited for turf applications in shady situations.

The objective of this research was to measure the effect of imposed shade upon the growth characteristics of a range of warm season grasses.

**METHODS**

Plastic bins 570mm x 350mm x 150mm depth were filled with a sand growing medium and established with selected grasses (Table 1) on 22 October 1991. The grasses were established by removing eight cores 50mm diameter x 100mm depth from established turf areas maintained at the Australian Turfgrass Research Institute, and transplanting them into the plastic bins.
Table 1. Grasses used in the experiment

<table>
<thead>
<tr>
<th>Species and Cultivar</th>
<th>Common Name</th>
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</thead>
<tbody>
<tr>
<td><em>Pennisetum clandestinum</em></td>
<td>Kikuyu grass</td>
</tr>
<tr>
<td><em>Dactyloctenium anstrale</em></td>
<td>Durban grass</td>
</tr>
<tr>
<td><em>Stenotaphrum secundatum</em></td>
<td>Buffalo grass</td>
</tr>
<tr>
<td><em>Cynodon dactylon 'Wintergreen'</em></td>
<td>Wintergreen couch grass</td>
</tr>
<tr>
<td><em>Cynodon dactylon x Cynodon transvaalemis</em> cv. 'Tifdwarf'*</td>
<td>Tifdwarf couch grass</td>
</tr>
<tr>
<td><em>Cynodon dactylon x Cynodon transvaalemis</em> cv. 'Santa Ana'*</td>
<td>Santa Ana couch grass</td>
</tr>
<tr>
<td><em>Cynodon dactylon cv. C29</em></td>
<td>C29 couch grass</td>
</tr>
</tbody>
</table>

a Note: U.S.A. *S. secundatum = "St. Augustine grass"

b Note: U.S.A. *Cynodon spp. = "Bermuda grass"

Six bins of each of the seven grasses were allowed to establish a complete grass cover in full sunlight, with periodic clipping using scissors to encourage lateral spread of the plants. On 24 January 1992, the six bins of each grass were randomly assigned to either full sunlight or shade, giving 3 replicates under each environment. All of the shade bins were grouped under two horizontal frames at 300mm height, which were covered with '50% shadecloth'. The bins were randomly positioned under the shadecloth frames and located at least 200mm from the edges of the frames.

Clippings were removed to measure leaf growth rate (kg ha\(^{-1}\) d\(^{-1}\)) and the specific leaf area, S.L.A. (cm\(^2\) g\(^{-1}\)). Grass samples were cut from a randomly located quadrat within each bin, which measured 150mm x 150mm for kikuyu, buffalo and durban grass, and 50mm x 50mm for the couch grasses. The leaves of the fresh grass samples were separated from stem tissue by hand and then passed through an electronic scanning leaf area machine. The leaf samples were then dried in an oven at 80°C for at least 24 hours before weighing.

The bins were clipped by hand at approximately 14 day intervals during the course of the experiment, as follows:

- 24/1/92 Treatments imposed
- 11/2/92 Bins clipped
- 26/2/92 to 27/2/92 February sampling
- 28/2/92 Bins clipped
- 12/3/92 to 20/3/92 March sampling
- 20/3/92 Bins in full sunlight clipped
- 23/3/92 Bins in shade clipped
- 13/4/92 to 23/4/92 April sampling

The bins were irrigated by hand with a hose and nozzle, with scheduling determined by visual evaluation of turfgrass and soil condition.

The incident solar radiation received under full sunlight and shade conditions was monitored with two Megatron Integrating Photometers (Trickett and Moulsley, 1956). A photo cell was placed at turfgrass level in each light environment and connected to an electrolytic integrating D.C. meter, which was calibrated to measure gram calories per square centimetre (g cal. cm\(^{-2}\)). Radiation measurements were made from 8/4/92 until 28/4/92.
The growth rate (kg ha\(^{-1}\) d\(^{-1}\)) and specific leaf area (cm\(^2\) g\(^{-1}\)) data for each grass and observation date was statistically analysed by separate Student t-tests using MASS computer software. If the ratio between the two sample variances (i.e. light and shade) was large, the MASS software also calculated the Aspen-Welch statistic. The Aspen-Welch probability statistic was used for mean separation in these cases, and is an approximate t-statistic with a calculated fractional degrees of freedom.

RESULTS

Light radiation received under full sunlight and under the shadecloth from 8/4/92 until 28/4/92 was 5161.1 and 2037.9g cal. cm\(^{-2}\) respectively. From these measurements, the shadecloth reduced radiation by 39.5%.

The effect of shade upon the growth rate of the leaves of the seven grasses was variable (Table 2). In all but one case, large standard deviations resulted in no significant difference in the growth rate between full sunlight and shade. The mean growth rate increased in 50% of cases and decreased 50% of the time. In most cases, the difference in mean growth rate was <20%. Therefore, the degree of shade imposed did not have a major effect upon the growth rate of six of the seven grasses. The growth rate of *C. dactylon* cv. C29 was significantly increased (p < 0.05) under shade by 56% on one observation date and increased by 26% on another.

The growth rate of Durban grass in light or shade exceeded that of kikuyu and buffalo grass on each respective observation date. Buffalo grass also tended to grow at a faster rate than kikuyu. Of the couch grasses, the cultivar C29 produced the greatest growth rate under shade on both observation dates.

Table 2. Growth rate of seven warm season grasses grown under full light and under shade.

<table>
<thead>
<tr>
<th>Grass and month of observation</th>
<th>Growth rate (kg ha(^{-1}) d(^{-1}))</th>
<th>Change (^{a}) (%)</th>
<th>Significance Level (^{b})</th>
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<tbody>
<tr>
<td></td>
<td>Light</td>
<td>Shade</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March 1992</td>
<td>29.5 ± 6.9(^{c})</td>
<td>32.5 ± 1.4</td>
<td>10</td>
</tr>
<tr>
<td>April 1992</td>
<td>33.7 ± 5.7</td>
<td>28.7 ± 5.9</td>
<td>-15</td>
</tr>
<tr>
<td><em>D. australis</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>February 1992</td>
<td>54.7 ± 5.1</td>
<td>46.8 ± 0.5</td>
<td>-14</td>
</tr>
<tr>
<td>March 1992</td>
<td>64.9 ± 9.4</td>
<td>75.3 ± 13.2</td>
<td>16</td>
</tr>
<tr>
<td>April 1992</td>
<td>53.2 ± 9.8</td>
<td>45.9 ± 4.4</td>
<td>-14</td>
</tr>
<tr>
<td><em>S. secundatum</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>February 1992</td>
<td>27.7 ± 9.5</td>
<td>28.7 ± 8.0</td>
<td>4</td>
</tr>
<tr>
<td>March 1992</td>
<td>41.3 ± 6.1</td>
<td>47.3 ± 2.9</td>
<td>15</td>
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<tr>
<td>April 1992</td>
<td>32.0 ± 8.6</td>
<td>35.5 ± 2.2</td>
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<tr>
<td><em>C. dactylon</em> cv. ‘Wintergreen’</td>
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<tr>
<td>March 1992</td>
<td>51.5 ± 13.2</td>
<td>43.9 ± 10.3</td>
<td>-15</td>
</tr>
<tr>
<td>April 1992</td>
<td>50.7 ± 8.9</td>
<td>40.9 ± 2.9</td>
<td>-19</td>
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<td></td>
<td></td>
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<tr>
<td>March 1992</td>
<td>39.3 ± 9.9</td>
<td>39.9 ± 4.2</td>
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</tr>
<tr>
<td>April 1992</td>
<td>35.6 ± 3.9</td>
<td>32.6 ± 2.6</td>
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</tr>
<tr>
<td><em>C. dactylon</em> x C. transvaalensis* cv. ‘Santa Ana’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March 1992</td>
<td>57.8 ± 2.2</td>
<td>50.2 ± 17.3</td>
<td>-13</td>
</tr>
<tr>
<td>April 1992</td>
<td>48.4 ± 5.6</td>
<td>39.4 ± 4.2</td>
<td>-19</td>
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<td><em>C. dactylon</em> cv. C29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March 1992</td>
<td>33.7 ± 9.4</td>
<td>52.7 ± 4.0</td>
<td>56</td>
</tr>
<tr>
<td>April 1992</td>
<td>43.1 ± 8.3</td>
<td>54.2 ± 2.6</td>
<td>26</td>
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</table>

\(^{a}\) Change in growth rate from light to shade.

\(^{b}\) NS = not significant (p > 0.05), * = p < 0.05

\(^{c}\) Mean and standard deviation of 3 replicates
The high degree of variability between the replicate growth rate observations was not surprising, considering the area of grass which was cut (Methods). The sample size was selected to provide a manageable number of grass leaves for S.L.A. measurement. The growth rate data was of secondary importance, however the results provide useful indications of the relative growth rate between grasses and between light environments.

In all but two cases, the S.L.A. of the seven grasses increased under shade, as expected (Table 3). The decreased S.L.A. values were measured on couch grasses and contrasted with increased mean S.L.A. on the other observation dates. The data for the couch grasses was particularly variable, which may be at least partially due to errors generated by the leaf area machine. The machine was calibrated to read mm², and was regularly checked against standards of a similar size to the couch grass leaves. However, during operation of the machine it was noted that some leaves escaped detection. The problem was not evident with the coarser-leaved grass species (*P. clandestinum*, *D. aitstrale* and *S. secundatum*).

The high variability between replicate couch grass samples resulted in no significant differences (p > 0.05) in S.L.A. for all but the Santa Ana cultivar in April. The results indicate that Santa Ana is the least tolerant of the four couch grasses to shade.

Table 3. Specific leaf area (S.L.A.) of seven warm season grasses grown under full light and under shade.

<table>
<thead>
<tr>
<th>Grass and month of observation</th>
<th>S.L.A. (cm² g⁻¹)</th>
<th>Change a (%)</th>
<th>Significance Level b</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. clandestinum</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>March 1992</td>
<td>302 ± 24c</td>
<td>417 ± 13</td>
<td>38 **</td>
</tr>
<tr>
<td>April 1992</td>
<td>293 ± 30</td>
<td>365 ± 10</td>
<td>24 NS</td>
</tr>
<tr>
<td><em>D. aitstrale</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>February 1992</td>
<td>140 ± 3</td>
<td>165 ± 14</td>
<td>18 NS</td>
</tr>
<tr>
<td>March 1992</td>
<td>280 ± 28</td>
<td>331 ± 8</td>
<td>18 NS</td>
</tr>
<tr>
<td>April 1992</td>
<td>250 ± 17</td>
<td>300 ± 9</td>
<td>20 *</td>
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<tr>
<td><em>S. secundatum</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>February 1992</td>
<td>125 ± 18</td>
<td>244 ± 11</td>
<td>95 ***</td>
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<td>March 1992</td>
<td>237 ± 2</td>
<td>321 ± 9</td>
<td>35 *</td>
</tr>
<tr>
<td>April 1992</td>
<td>212 ± 16</td>
<td>288 ± 17</td>
<td>36 *</td>
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<tr>
<td><em>C. dactylon cv. 'Wintergreen'</em></td>
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<tr>
<td>March 1992</td>
<td>95 ± 8</td>
<td>101 ± 31</td>
<td>6 NS</td>
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<tr>
<td>April 1992</td>
<td>60 ± 16</td>
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<td>96 ± 35</td>
<td>84 ± 15</td>
<td>-12 NS</td>
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<td>March 1992</td>
<td>82 ± 19</td>
<td>127 ± 38</td>
<td>55 NS</td>
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<td>April 1992</td>
<td>48 ± 8</td>
<td>83 ± 8</td>
<td>72 **</td>
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<tr>
<td>March 1992</td>
<td>77 ± 16</td>
<td>90 ± 21</td>
<td>17 NS</td>
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<tr>
<td>April 1992</td>
<td>152 ± 39</td>
<td>132 ± 17</td>
<td>-14 NS</td>
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</table>

a Change in S.L.A. from light to shade.
b NS = not significant (p >0.05); * = p < 0.05; ** = p < 0.01; *** = p < 0.001.
c Mean and standard deviation of 3 replicates
Buffalo grass (*S. secundatum*) was the least tolerant of the three coarse-textured grasses to shade, producing highly significant (p < 0.01) increases in S.L.A. on all three observation dates. Beard (1973) referred to work by Burton and Deal, and concluded that *S. secundatum* was "the outstanding warm season turfgrass in terms of shade tolerance". However, from another report by Burton et al. (1959), it would appear that *S. secundatum* was compared with *Cynodon* spp., zoysiagrass (*Zoysia* spp.) and bahiagrass (*Paspalum notatum*), and neither *P. clandestinum* nor *D. australis*.

Kikuyu had intermediate shade tolerance and Durban grass had the greatest shade tolerance (i.e. produced the smallest change in S.L.A.). The shade tolerance of Durban grass is widely appreciated in Australia, however the evidence is circumstantial.

ACKNOWLEDGEMENTS

The assistance of Dr. Peter Martin in the design, implementation and report for this experiment is gratefully acknowledged. Furthermore, the technical assistance by ground staff, David Westall and sadly the late Anthony McNeill was invaluable. Mrs. Angelene Smith and a team of Sydney University students completed much of the laborious leaf tissue sampling and measurements.

REFERENCES


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<th>TRT</th>
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<th>DATE CUT</th>
<th>LAST CUT</th>
<th>DAYS</th>
<th>DRY WT (g)</th>
<th>LEAF (cm²)</th>
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<td>28/02/92</td>
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<td>0.65</td>
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