EVALUATION OF TURF GRASS SPECIES SUITABLE FOR TROPICAL CONDITIONS BASED ON QUANTITATIVE AND QUALITATIVE TRAITS

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INTRODUCTION
In modern urban living, turfgrasses play significant role in enhancing quality of life. turfgrass provides functional (i.e., soil erosion reduction, dust prevention, heat dissipation, wild habitat), recreational (i.e., low cost surfaces, physical and mental health) and aesthetic (i.e., beauty, quality of life, increased property values) benefits to society and the environment (Fender, 2006; King and Balogh, 2006). The turfgrass industry is considered to be a billion dollars industry which has an impact on the environment as well. A lush green turf is a dream for every green keeper. Establishing and maintaining quality turf requires ensured supply of quality irrigation water which is the most important challenge worldwide. Turfgrasses are among the most important plant groups that are used extensively in the landscape of new cities, coastal resorts and touristic villages. Turf grass is the most important groundcover in the world and knowledge of relative drought resistance is important for selecting turf grass that can sustain during drought period (Fu et al., 2005).

Drought is the condition resulting from dry weather, capable of damaging plant by shortening the supply of water as in the tropical condition. That shortage in water supply causes water stress to plant. Turk growth and development is affected by water stress as observed in different ways and the most important effect can be seen on the cell division and growth (Mckersie and Leshem, 1994), phytohormones (Drolet et al., 1986; Smirnoff and Cumbes, 1989) stomata opening and gas exchange (Turner et al., 1978) and photosynthesis (Bjorkman and Powles, 1984; Chaves, 1991; Cornic and Briantais, 1991; Lawlor, 1995). Some types of turfgrasses have the ability to avoid tissue-damage while growing in a water stress environment. This avoidance may be due to the increased root depth and root water uptake properties. On the other hand, reduction in the evapo-transpiration through reduced leaf surface area, stomata closure and leaf surface properties such as epidermal hair and wax are foliage adaptations. The other mechanism by which turfgrasses overcome the water stress is through the ability of some varieties to endure low (more negative) water potentials caused by water stress. Turfgrass water requirements differ from species to species, zone to zone and from season to season. Turfgrass mostly fulfill their water need from soil moisture, dew and rainfall. On the other hand they lose most of it by evapotranspiration, especially in the tropical areas.

Turf grass is mainly used for lawns, athletic fields, and golf courses where proper selection and care of turf grass depends upon knowledge of the environmental adaptation, cultural requirements and quality features of a number of grass species. Drought stress is a major limiting factor for both cool-season and warm-season grasses. For making the turfgrasses water stress tolerant, understanding about plant responses to water-limited environment is of great importance. Plant tolerance to drought results from both morphological adaptation and responses at the biochemical and genetic levels (Levitt, 1972). Maintaining good quality turf in the tropical region is a difficult task and people are searching for turfgrass species or cultivars that will perform well in harsh environmental conditions.

ABSTRACT
Turf grasses play a vital role in enhancing quality of life in contemporary urban livelihood. Water quantity is the most important challenge worldwide in establishing and maintaining quality turf. The present study was aimed to investigate the performance of twelve native turfgrasses under tropical condition. Morphological, physiological parameters and visual quality (shoot color, shoot density and shoot uniformity) were also recorded. It was found that temperature has significant effect on the performance of turfgrasses. Bermuda grass which had the highest root length (41.59 cm), root density (8.08), dry weight of root (5.04), turf quality (8.53/29), total chlorophyll (1.24 mg g$^{-1}$), relative water content (85.62 %) and stomatal index (upper) (26.94 %) was found to be most drought tolerant followed by Zoysia japonica which is best suitable for stress tolerant conditions.
dense turf could contribute to environmental improvement through the reduction of solar radiation intensity associated with the sunny climate.

Environmental stress is among the major issues in agriculture and turfgrass management and almost nowhere the plants/turfgrasses are immune to the adverse effects of drought. Hence, to find the most tolerant turfgrass species/cultivars to drought resistance and their uses under such conditions would probably be one of the most logical and effective solutions of the stress problems (Pessarakli and Kpoec, 2009). Studies are being carried out regarding turfgrass species in tropical areas. Research related to plant response to water stress is becoming increasingly important because changing climatic scenario is increasing aridity in many areas of the globe (Petit et al., 1999).

It is now known that extent of drought tolerance varies from species to species in almost all plant species (Lin et al., 2006). Drought tolerance, particularly in grasses is associated closely with their morphological and physiological traits (Bahrani et al., 2010). Although, the general effects of drought on plant growth are quite well known, the primary effects of water deficit at the biochemical and molecular levels are not well understood (Chaves et al., 2003, Zivcak et al., 2008; Jaleel et al., 2008). Hence, the objective of the study was to investigate the performance of twelve native turf-grasses suitable for tropical condition to establish a baseline for adaptability of turf grass species under drought condition and selection of turfgrass according to the stress tolerance.

MATERIALS AND METHODS

The present research was conducted at Botanical Garden, Department of Floriculture and Landscaping, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, which is geographically situated at an altitude of 426.72 meters above mean sea level (MSL) and between 11° 02” North latitude and 76°57” East longitude.

Twelve turfgrass genotypes were collected and evaluated from in and around Coimbatore district viz., Axonopus compressus, Brachiaria rupiformis, Digitaria bicolor, Cenchrus ciliaris, Cynodon dactylon X Cynodon transvaalensis, Daicyoctenium aegyptium, Ophiopogon japonicus, Paspalum vaginatum, Stenotaphrum secundatum, Stenotaphrum secundatum ‘Variegata’, Zoysia japonica and Zoysia tenuifolia.

The experiment was laid out in Randomized Block Design (RBD) with four replicates. Planting was done by adopting sprinkling method. The experimental plots of size of 1 x 1 m2 were prepared with a spacing of 0.5 m x 0.5 m between the plots. The plots were bordered with hollow block and bricks. The plots were uniformly filled with red sand and river soil in the ratio of 2:1. The sods were planted using sprinkling method. All experimental plots were irrigated with five liter of water per day per square where ambient temperature ranged from 21 to 36°C.

The following observations were recorded at 60 and 120 days after transplanting viz., leaf area / cm², shoot length, shoot density, root length, root density (Morris and Shearman, 2000), fresh weight of root, dry weight of root (Lee et al., 2004), fresh weight of shoot, dry weight of shoot (Huang et al., 1997), turf quality (Morris and Shearman, 2000), turf growth habit (Dianne and Tom, 2005), leaf texture, leaf blade colour and Ligule (Morris and Shearman, 2000). Physiological parameters viz., total chlorophyll (Yoshida, et al., 1971) proline (Bates et al., 1973), relative water content (Weatherly, 1950) and stomatal index (Salisbury, 1927) were analyzed. Data obtained from the experiment were analyzed by using 'F' test for significance following the methods described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Data pertaining to physical parameters and physiological parameters were showed significant differences between twelve varieties. In the present study, leaf area has recorded significant difference among the twelve grass species (Table. 1, 2 and 3). Kallenbach (1914) reported that larger leaf area ends up in increased carbohydrate storage in leaf structure whereas Stenotaphrum secundatum ‘Variegata’ (10.59 cm²) had the largest leaf area and hence greater carbohydrate which in turn means more photosynthesis. Lower leaf area was recorded in Zoysia japonica (0.87 cm²) followed by Zoysia tenuifolia (0.81 cm²) and this trait is responsible for reducing the transpiration rate by lowering the stomatal activity (Parsons, 1982). This character plays a significant role in adaptations to arid environment (Erickson et al., 2004).

The highest shoot length was registered in Stenotaphrum secundatum (51.50 cm). It might be related to various factors which influence the shoot growth rate, one of them being ethylene production which has been reported to influence the shoot growth in turf grasses under stress conditions (Verslues et al., 1998). Shoot length of grass species is also significantly affected by soil type, as observed by Basha (2007). Shoot density recorded significant difference among the twelve grass species evaluated in the present study. This may be attributed to their inherent differences. The characters high shoot density, low leaf area and prostrate growing habit were observed in Zoysia japonica (85.19%). Similar characters were also reported by Kim (1983) suggested that these traits lead to low ET rates. Even though Stenotaphrum secundatum (85.01%) has high shoot density and prostrate growth, it has larger leaf area which is not favourable to have low ET rates. Increased shoot density is also responsible for increased canopy resistance against abiotic stress (Kim and Beard, 1988; Shearman, 1989).

Cynodon dactylon X Cynodon transvaalensis (8.08) showed the highest root density and medium depth among the species studied. Rooting density of both trees and turf grasses decreases as depth in the soil profile increases, and is found mostly in the top 30 cm of the soil profile (Kozlowski and Pallardy, 1997; Stewart et al., 2005; Turgeon, 2002). Cynodon dactylon X Cynodon transvaalensis (14.59 cm) is deeper compared to the other grasses studied.

Chen et al. (2012) stated that this trait is adopted by grasses to obtain water and nutrients with minimum energy consumption. Deeper rooting has been associated with drought avoidance and tolerance in many species of turf
Table 1: Leaf area, root and shoot length and shoot and root density at 60 and 120 DAP

<table>
<thead>
<tr>
<th>Species/Parameters</th>
<th>Leaf area (cm²)</th>
<th>Root length</th>
<th>Shoot length</th>
<th>Shoot density</th>
<th>Root density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axonopus compressus</td>
<td>9.34</td>
<td>5.30</td>
<td>13.50</td>
<td>7.96</td>
<td>17.30</td>
</tr>
<tr>
<td>Bracharia ramosa</td>
<td>5.71</td>
<td>4.60</td>
<td>12.20</td>
<td>21.01</td>
<td>24.40</td>
</tr>
<tr>
<td>Digitaria ciliaris</td>
<td>1.99</td>
<td>5.20</td>
<td>12.00</td>
<td>8.20</td>
<td>38.50</td>
</tr>
<tr>
<td>Zoysia japonica</td>
<td>7.79</td>
<td>9.30</td>
<td>12.30</td>
<td>19.14</td>
<td>48.50</td>
</tr>
<tr>
<td>Cynodon dactylon x</td>
<td>1.21</td>
<td>4.65</td>
<td>14.59</td>
<td>21.17</td>
<td>25.55</td>
</tr>
<tr>
<td>Cynodon transvaalensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dactyloctenium aegyptium</td>
<td>3.98</td>
<td>4.50</td>
<td>12.00</td>
<td>6.02</td>
<td>12.60</td>
</tr>
<tr>
<td>Ophiopogon japonicus</td>
<td>2.57</td>
<td>4.10</td>
<td>6.20</td>
<td>3.80</td>
<td>8.50</td>
</tr>
<tr>
<td>Paspalum vaginatum</td>
<td>1.39</td>
<td>5.40</td>
<td>10.20</td>
<td>10.30</td>
<td>22.50</td>
</tr>
<tr>
<td>Stenotaphrump secundatum</td>
<td>8.86</td>
<td>7.80</td>
<td>11.50</td>
<td>10.62</td>
<td>51.50</td>
</tr>
<tr>
<td>Stenotaphrump secundatum 'Variegata'</td>
<td>10.59</td>
<td>5.30</td>
<td>9.03</td>
<td>13.16</td>
<td>46.50</td>
</tr>
<tr>
<td>Zoysia japonica</td>
<td>0.87</td>
<td>5.50</td>
<td>7.60</td>
<td>4.96</td>
<td>9.10</td>
</tr>
<tr>
<td>Zoysia tenuifolia</td>
<td>0.81</td>
<td>7.40</td>
<td>8.09</td>
<td>5.10</td>
<td>8.10</td>
</tr>
<tr>
<td>Mean</td>
<td>4.56</td>
<td>5.56</td>
<td>11.63</td>
<td>10.25</td>
<td>25.75</td>
</tr>
<tr>
<td>CD @ 0.05 %</td>
<td>0.33</td>
<td>0.16</td>
<td>0.31</td>
<td>0.31</td>
<td>0.87</td>
</tr>
<tr>
<td>SD</td>
<td>0.16</td>
<td>0.33</td>
<td>0.64</td>
<td>0.64</td>
<td>1.78</td>
</tr>
</tbody>
</table>

Table 2: Fresh weight of shoot and root, dry weight of shoot and root and turf quality at 60 and 120 DAP

<table>
<thead>
<tr>
<th>Species/Parameters</th>
<th>Fresh wt. of shoot</th>
<th>Dry wt. of shoot</th>
<th>Fresh wt. of root</th>
<th>Dry wt. of root</th>
<th>Turf quality (1-9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axonopus compressus</td>
<td>7.32</td>
<td>15.13</td>
<td>1.53</td>
<td>2.96</td>
<td>3.32</td>
</tr>
<tr>
<td>Bracharia ramosa</td>
<td>20.98</td>
<td>30.41</td>
<td>4.33</td>
<td>9.90</td>
<td>3.98</td>
</tr>
<tr>
<td>Digitaria ciliaris</td>
<td>11.45</td>
<td>24.78</td>
<td>1.25</td>
<td>4.20</td>
<td>1.45</td>
</tr>
<tr>
<td>Cynodon dactylon x</td>
<td>17.88</td>
<td>30.17</td>
<td>2.59</td>
<td>4.90</td>
<td>5.76</td>
</tr>
<tr>
<td>Cynodon transvaalensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dactyloctenium aegyptium</td>
<td>6.40</td>
<td>12.12</td>
<td>0.74</td>
<td>1.79</td>
<td>2.40</td>
</tr>
<tr>
<td>Ophiopogon japonicus</td>
<td>4.30</td>
<td>10.10</td>
<td>1.45</td>
<td>3.12</td>
<td>1.97</td>
</tr>
<tr>
<td>Paspalum vaginatum</td>
<td>10.30</td>
<td>23.43</td>
<td>1.12</td>
<td>3.18</td>
<td>1.30</td>
</tr>
<tr>
<td>Stenotaphrump secundatum</td>
<td>23.63</td>
<td>42.37</td>
<td>6.67</td>
<td>10.08</td>
<td>3.63</td>
</tr>
<tr>
<td>Stenotaphrump secundatum 'Variegata'</td>
<td>18.91</td>
<td>35.98</td>
<td>2.69</td>
<td>5.53</td>
<td>2.91</td>
</tr>
<tr>
<td>Zoysia japonica</td>
<td>6.11</td>
<td>15.42</td>
<td>2.12</td>
<td>4.03</td>
<td>4.11</td>
</tr>
<tr>
<td>Zoysia tenuifolia</td>
<td>3.13</td>
<td>8.84</td>
<td>0.89</td>
<td>2.46</td>
<td>3.76</td>
</tr>
<tr>
<td>Mean</td>
<td>12.11</td>
<td>26.47</td>
<td>2.49</td>
<td>5.32</td>
<td>4.22</td>
</tr>
<tr>
<td>CD @ 0.05 %</td>
<td>0.36</td>
<td>0.77</td>
<td>0.09</td>
<td>0.12</td>
<td>0.16</td>
</tr>
<tr>
<td>SD</td>
<td>0.73</td>
<td>1.57</td>
<td>0.18</td>
<td>0.24</td>
<td>0.32</td>
</tr>
</tbody>
</table>

(Carrow, 1996, Huang et al., 1997) and other crops. It showed deeper root system, hence it may tolerate drought and infrequent irrigation. Dry weight is associated with the growth rate of a grass species. Stenotaphrum secundatum (10.08 g) had higher shoot dry weight, implying that this grass species had greater growth rate compared to the other turf species. This may be due to the inherent genetic trait that is responsible for greater growth rate. Increased biomass is also directly related to greater photosynthetic activity of the grass species. Cynodon dactylon X Cynodon transvaalensis (5.04g) has higher root dry weight compared to other species.

The percentage relative water content (RWC) was determined as an indicator of osmotic status of turfgrass species studied. RWC is an important indicator of water deficit stress in leaves (Sairam et al., 1997) gives a picture of cell membrane stability. Highest RWC was observed in the Cynodon dactylon x Cynodon transvaalensis grass (85.62 %), followed by Paspalum vaginatum (84.22%). The maintenance of healthy turf, particularly during stressful periods is partially dependent on the water content which is more important for recovery from injury or stress. Stress exposed plants were reported to have reduced RWC of their leaves (Singh et al., 2014). During stress, the plasma membrane and the membranes of other organelles lose their permeability due to molecular modifications of the lipid bilayer, initially promoted by oxidative processes (Hopkins et al., 2007). Similar observations were also reported in this study (Table 3) decrease in RWC turf grass species under osmotic stress.

Total chlorophyll content decreased under salt stress in different turfgrass species (Table 3) Interaction effect of salinity and species was significant (p <0.05) for total chlorophyll Turf species with higher chlorophyll-a and chlorophyll-b contents, under control conditions, also had higher amounts of total chlorophyll. While Cynodon dactylon x Cynodon transvaalensis (1.24 mg g⁻¹) had higher total chlorophyll under stress conditions with marginal reductions compared to other turf species. Chlorophyll degradation is the primary cause of photosynthetic degeneration and a main biochemical factor...
for the observed growth reduction (Everard et al., 1994). Similar observations were also made in wheat where the osmotic stress accelerated the rate of chlorophyll and carotenid degradation which was decreased by 40 and 18 % respectively in stressed seedlings (Nagar et al., 2015). The Salinity-induced chlorophyll reduction may also be related either to Mg deficiency and/or chlorophyll oxidation since reactive oxygen species (ROS) generation is common in salinity stressed conditions (Moradi et al., 2007).

The mean stomatal index per cent per 0.156 mm² for abaxial and adaxial surface of different grass species are presented in Table 3. Among the grass species, the stomatal index percentage varies between the species and also between the adaxial and abaxial surface of the grass leaf. The highest stomatal index for adaxial surface leaves was measured and the highest S.I. was measured in the treatments Zoysia tenuifolia (26.94 per cent) and it was on par with the treatments Cynodon dactylon (26.12 per cent) when compared with the turf grass species. The highest stomatal index for abaxial surface was observed in the treatment Stenotaphrum secundatum (24.69 per cent), and it was on par with the treatments Zoysia tenuifolia (24.32 per cent). Turfgrass has limited stomatal control over transpiration as a result of low height and a thick boundary layer where the leaf surface is completely decoupled from conditions in the air outside the boundary layer (Javis and McNaughton, 1986). Thus, the evapotranspiration continued even when stomata closed (Harris and Tullberg, 1980), during which water is plausibly lost through the cuticle resulting in rapid water depletion in soil. In addition, turf species with lower stomatal index did not moderate internal water potential through stomatal closure, which means the rate of water potential decline in plants was rapid even when stomatal closure occurred immediately after withholding irrigation. Rapid decline in water potential was likely the result of greater boundary layer control over total transpiration from the canopy than stomatal aperture (Zhang et al., 2007).

Results on turf quality was assessed based on scoring techniques indicated that Cynodon dactylon X Cynodon transvaalensis (8.59 had high scores) (Table 4). Leaf texture of grass species varies from coarse to fine. Inherent differences among grass species might be the main factor for such variation in the trait leaf texture. Patton and Boyd (2008) stated that turf grass texture refers to leaf width, with coarse textured grasses having wider leaves and fine textured grasses having thinner leaves. Similar results were observed in this study Brachiaria reptans and Digitaria bicornis were found to have coarse

<table>
<thead>
<tr>
<th>Species/ Parameters</th>
<th>Growth habit</th>
<th>Ligule</th>
<th>Blade colour</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axonopus compressus</td>
<td>Stoloniferous</td>
<td>Membranous</td>
<td>Light green</td>
<td>Hairy</td>
</tr>
<tr>
<td>Bracharia reptans</td>
<td>Bunch</td>
<td>Fringe of Hairs</td>
<td>Dull green</td>
<td>Hairy</td>
</tr>
<tr>
<td>Digitaria bicornis</td>
<td>Stoloniferous</td>
<td>Hairy</td>
<td>Dull green</td>
<td>Hairy</td>
</tr>
<tr>
<td>Cenchrus ciliaris</td>
<td>Bunch/ Rhizomatous</td>
<td>Fringe of Hairs</td>
<td>Dull green</td>
<td>Hairy</td>
</tr>
<tr>
<td>Cynodon dactylon x Cynodon transvaalensis</td>
<td>Rhizomatous / Stoloniferous</td>
<td>Fringe of hairs</td>
<td>Green</td>
<td>Hairy</td>
</tr>
<tr>
<td>Dactyloctenium aegyptium</td>
<td>Stoloniferous / Rhizomatous</td>
<td>Membranous</td>
<td>Green</td>
<td>Hairy</td>
</tr>
<tr>
<td>Ophiopogon japonicus</td>
<td>Bunch / Rhizomatous</td>
<td>Absent</td>
<td>Dark green</td>
<td>Smooth</td>
</tr>
<tr>
<td>Paspalum vaginatum</td>
<td>Stoloniferous/ Rhizomatous</td>
<td>Membranous</td>
<td>Light green</td>
<td>Smooth</td>
</tr>
<tr>
<td>Stenotaphrum secundatum</td>
<td>Stoloniferous</td>
<td>Fringe of hairs</td>
<td>Light green</td>
<td>Smooth with prominent midrib</td>
</tr>
<tr>
<td>‘Variegata’</td>
<td>Stoloniferous</td>
<td>Hairy</td>
<td>Variegated green</td>
<td>Smooth with prominent white midrib with glossy back</td>
</tr>
<tr>
<td>Zoysia japonica</td>
<td>Rhizomatous</td>
<td>Fringe of hairs</td>
<td>Green</td>
<td>Smooth</td>
</tr>
<tr>
<td>Zoysia tenuifolia</td>
<td>Rhizomatous</td>
<td>Fringe of hairs</td>
<td>Dark green</td>
<td>Smooth with glossy back</td>
</tr>
</tbody>
</table>

Table 4: Growth habit, ligules, blade colour and texture of the turf grass species

<table>
<thead>
<tr>
<th>Species/ Parameters</th>
<th>Total Chlorophyll</th>
<th>Relative water content(%)</th>
<th>Stomatal index in upper (Adaxial) (%)</th>
<th>Stomatal index in Bottom (Abaxial) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axonopus compressus</td>
<td>1.01</td>
<td>80.98</td>
<td>20.59</td>
<td>19.05</td>
</tr>
<tr>
<td>Bracharia reptans</td>
<td>0.99</td>
<td>80.52</td>
<td>21.05</td>
<td>22.22</td>
</tr>
<tr>
<td>Digitaria bicornis</td>
<td>1.01</td>
<td>80.64</td>
<td>20.99</td>
<td>21.43</td>
</tr>
<tr>
<td>Cenchrus ciliaris</td>
<td>0.96</td>
<td>78.75</td>
<td>22.35</td>
<td>21.88</td>
</tr>
<tr>
<td>Cynodon dactylon x Cynodon transvaalensis</td>
<td>1.24</td>
<td>85.62</td>
<td>26.94</td>
<td>23.44</td>
</tr>
<tr>
<td>Dactyloctenium aegyptium</td>
<td>0.95</td>
<td>78.05</td>
<td>19.16</td>
<td>18.52</td>
</tr>
<tr>
<td>Ophiopogon japonicus</td>
<td>0.90</td>
<td>75.56</td>
<td>20.86</td>
<td>20.35</td>
</tr>
<tr>
<td>Paspalum vaginatum</td>
<td>1.22</td>
<td>84.22</td>
<td>19.44</td>
<td>17.27</td>
</tr>
<tr>
<td>Stenotaphrum secundatum</td>
<td>1.19</td>
<td>82.56</td>
<td>24.91</td>
<td>24.69</td>
</tr>
<tr>
<td>Stenotaphrum secundatum ‘Variegata’</td>
<td>1.08</td>
<td>82.27</td>
<td>19.05</td>
<td>18.75</td>
</tr>
<tr>
<td>Zoysia japonica</td>
<td>1.20</td>
<td>83.83</td>
<td>24.81</td>
<td>23.81</td>
</tr>
<tr>
<td>Zoysia tenuifolia</td>
<td>1.10</td>
<td>83.45</td>
<td>26.12</td>
<td>24.32</td>
</tr>
<tr>
<td>Mean</td>
<td>0.61</td>
<td>82.94</td>
<td>22.12</td>
<td>21.24</td>
</tr>
<tr>
<td>CD @ 0.05 %</td>
<td>0.02</td>
<td>1.98</td>
<td>0.53</td>
<td>0.51</td>
</tr>
<tr>
<td>SEd</td>
<td>0.03</td>
<td>4.04</td>
<td>1.09</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Table 3: Total chlorophyll, relative content and stomatal index of twelve turf grass species
texture with wider leaves, while Zoysia japonica, Zoysia tenuifolia, Paspalum vaginatum and Cynodon dactylon X Cynodon transvaalensis which are narrow leaved have fine texture. The fine textured and coarse textured grass species have their own merits and demerits. Fine textured leaves because of low surface area have reduced Evapo-Transpiration (ET) rate, whereas the coarse structured species are photosynthetically more active compared to the fine textured grasses. Hence, it is essential to choose the grass species based on specific requirements.

Some of the earliest classifications of grasses were based on stolon and leaf colour (Busey et al., 1982 and Busey, 1986). Darker the leaf colour, more is the chlorophyll content (Johnson, 1973). In the present study, dark green colour in Ophiopogon japonicus, Zoysia japonica and Zoysia tenuifolia and light green colour was observed in Axonopus compressus, Stenotaphrum secundatum, Stenotaphrum secundatum ‘Variegata’.

Ligule is a thin membrane-like structure or row of flimsy hairs at the junction of the leaf sheath and blade, formed entirely by an up growth of the ventral epidermis of the leaf, typically found in grasses and sedges (Philipson, 1935) and is used to identify the grass species at vegetative stage (Judziewicz & Clark, 1993; Zuloaga et al., 1998; Fuente & Ortunez, 2001). In the present study, hairy ligules were observed in Brachiaria reptans, Digitaria ciliaris, Cynodon dactylon X Cynodon transvaalensis, Stenotaphrum secundatum, Stenotaphrum secundatum ‘Variegata’, Zoysia japonica and Zoysia tenuifolia, whereas Axonopus compressus, Dactyloltenium aegyptium and Paspalum vaginatum showed membranous ligules. The above eleven grass species showed the presence of ligule on the adaxial surface which is a sign of fitness in grass. Similar observations have been reported earlier by Moreno et al. (1997) and Korzun et al. (1997).

Appropriate, realistic physiological criteria are essential to define the stress tolerance and growth responses of different turfgrass species. We conclude that among the twelve grass species studied Cynodon dactylon followed Zoysia japonica which gave overall plant tolerance to water stress based on the overall turf quality, morphological attributes, relative water content, stomatal index and total chlorophyll content. Many of the principles can be employed to discuss issues related to development of better direct selection criteria for other turfgrass species.

REFERENCES


Kim, K. S. 1983. Comparative evapotranspiration of thirteen turfgrasses grown under both non-limiting soil moisture and progressive water stress conditions. Master Thesis, Texas A&M University, College Station, TX.


Kim, K. S. 1983. Comparative evapotranspiration of thirteen turfgrasses grown under both non-limiting soil moisture and progressive water stress conditions. Master Thesis, Texas A&M University, College Station, TX.


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