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

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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 / 9), 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.

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. Turf 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. Turfgrasses 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. A 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 turf grass 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 turf grass 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 turf grass genotypes were collected and evaluated from in and around Coimbatore district *viz., Axonopus compressus*, *Brachiaria reptans*, *Digitaria bicornis*, *Cenchrus ciliaris*, *Cynodon dactylon X Cynodon transvaalensis*, *Dactyloctenium 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 sprigging method. The experimental plots of size of 1 x 1 m^2 were prepared with a spacing of 0.5 m × 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 sprigging 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 / cm^2, 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 cm^2) 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 cm^2) followed by *Zoysia tenuifolia* (0.81 cm^2) 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

Species/ Parameters	Leaf area (cm^2)	Root length		Shoot length		Shoot density		Root density	
		60 DAP	120 DAP	60 DAP	120 DAP	60 DAP	120 DAP	60 DAP	120 DAP
Axonopus compressus	9.34	5.30	13.50	7.96	17.30	35.00	75.00	3.50	5.50
Bracharia reptans	5.71	4.60	13.20	21.01	24.40	40.00	79.00	4.00	7.45
Digitaria bicornis	1.99	5.20	12.00	8.20	38.50	45.00	70.00	3.50	6.00
Cenchrus ciliaris	7.79	9.30	12.30	19.14	48.50	25.00	60.00	3.50	7.00
Cynodon dactylon x *Cynodon transvaalensis*	1.21	4.65	14.59	21.17	25.55	40.40	81.85	5.05	8.08
Dactyloctenium aegyptium	3.98	4.50	12.00	6.02	12.60	25.00	60.00	3.00	5.50
Ophiopogon japonicus	2.57	4.10	6.20	3.80	8.50	20.00	25.00	3.50	5.50
Paspalum vaginatum	1.39	5.40	10.20	10.30	22.50	25.00	75.00	3.50	6.00
Stenotaphrum secundatum	8.86	7.80	11.50	10.62	51.50	35.00	85.01	4.50	6.50
Stenotaphrum secundatum ' Variegata'	10.59	5.30	9.03	13.16	46.50	30.00	80.03	3.50	5.00
Zoysia japonica	0.87	5.50	7.60	4.96	9.10	25.00	85.19	4.50	7.50
Zoysia tenuifolia	0.81	7.40	8.09	5.10	8.10	25.00	80.09	4.50	7.50
Mean	4.56	5.56	11.63	10.25	25.75	30.75	68.98	3.87	6.44
CD @ 0.05 %	0.33	0.16	0.31	0.31	0.87	0.74	1.71	0.09	0.16
SEd	0.16	0.33	0.64	0.64	1.78	1.50	3.47	0.19	0.32

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

Species/ Parameters	Fresh wt. of shoot		Dry wt. of shoot		Fresh wt. of root		Dry wt. of root		Turf quality (1-9)	
	60 DAP	120 DAP	60 DAP	120 DAP	60 DAP	120 DAP	60 DAP	120 DAP	60 DAP	120 DAP
Axonopus compressus	7.32	15.13	1.53	2.96	3.32	7.34	0.75	1.87	7.00	7.50
Bracharia reptans	20.98	30.41	4.33	9.90	3.98	7.78	1.15	3.99	6.50	7.00
Digitaria bicornis	11.45	24.78	1.25	4.20	1.45	2.35	0.51	1.05	6.50	7.00
Cenchrus ciliaris	10.54	22.31	2.78	4.97	3.99	9.02	1.39	4.50	6.00	5.50
Cynodon dactylon x *Cynodon transvaalensis*	17.88	30.17	2.59	4.90	5.76	11.36	2.18	5.04	7.58	8.59
Dactyloctenium aegyptium	6.40	12.12	0.74	1.79	2.40	5.67	0.83	1.26	6.00	6.00
Ophiopogon japonicus	4.30	10.10	1.45	3.12	1.97	3.12	1.01	1.15	5.50	6.50
Paspalum vaginatum	10.30	25.34	1.12	3.18	1.30	3.18	0.90	1.99	5.50	7.00
Stenotaphrum secundatum	23.63	42.37	6.67	10.08	3.63	7.15	1.07	2.57	8.00	8.50
Stenotaphrum secundatum 'Variegata'	18.91	35.98	2.69	5.53	2.91	5.13	0.43	1.88	7.50	8.00
Zoysia japonica	6.11	15.42	2.12	4.03	4.11	9.93	0.91	2.60	6.50	7.50
Zoysia tenuifolia	3.13	8.84	0.89	2.46	3.76	8.56	2.68	3.13	6.00	7.50
Mean	12.11	26.47	2.49	5.32	4.22	9.09	1.59	3.15	6.52	7.19
CD @ 0.05 %	0.36	0.77	0.09	0.12	0.16	0.34	0.11	0.23	0.16	0.18
SEd	0.73	1.57	0.18	0.24	0.32	0.69	0.05	0.11	0.33	0.36

(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

Table 3: Total chlorophyll, relative content and stomatal index of twelve turf grass species

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

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

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

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 mm^2 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 stomatal index for adaxial surface leaves was measured and 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 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 bicornis, Cenchrus ciliaris, Cynodon dactylon X Cynodon transvaalensis, Stenotaphrum secundatum, Stenotaphrum secundatum* 'Variegata', *Zoysia japonica* and *Zoysia tenuifolia,* whereas *Axonopus compressus, Dactyloctenium 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

Bahrani, M. J., Bahrami, H. and Haghighi, A. A. K. 2010. Effect of water stress on ten forage grasses native or introduced to Iran. *Grassland Science*. **56:** 1-5.

Basha, S. M. 2007. *Studies on the growth and performance of turf grasses on different types of soil.* M.Sc. (Hort.). *Thesis submitted to Tamil Nadu Agricultural University, Coimbatore.*

Bates, L. S., Waldren, R. P. and Teare, I. D. 1973. Rapid determination of free proline for water-stress studies. *Plant Soil*. **39:** 205-207.

Bjorkman, O. and Powles, S. B. 1984. Inhibition of photosynthetic reactions under water stress: interaction with light level. *Planta*. **161:** 490-504.

Busey, P. 1986. Morphological identification of St. Augustinegrass cultivars. *Crop Science*. **26:** 28-32.

Busey, P., Broschat, T. and Center, B. 1982. Classification of St. Augustinegrass. *Crop Science*. **22:** 469-473.

Carrow, R.N. 1996. Drought avoidance characteristics of diverse tall fescue cultivars. *Crop Science*. **36:** 371-377.

Chaves, M. M. 1991. Effect of water deficits on carbon assimilation. *J. Experimental Botany*. **42:**1-16.

Chaves, M. M., Maroco, J.P. and Pereira, J. S. 2003. Understanding plant response to drought from genes to whole plant. *Functional Plant Biology*. **30:** 239-264.

Chen, Y. J., Zhang, L., He, Y. B., Gao, Y. and Wang, C. 2012. Drought stress effects on relative growth rate and biomass allocation of three kentucky bluegrass (*Poa pratensis*) Cultivars. *Acta Horticulture*. **938:** 137-144.

Cornic, G. and Briantais, J. M. 1991. Partitioning of photosynthetic electron flow between CO_2 and O_2 reduction in a C_3 leaf (*Phaseolus vulgaris*) at different CO_2 concentrations and during drought stress. *Planta*. **183:** 178-184.

Dianne, P. and Tom, V. 2005. Identifying turf and weedy grasses of the Northen United States. *Univeristy of Illinois Extension*. p. 64.

Drolet, G., Dumdroff, E. B., Legge, R. I. and Thompson, J. E. 1986. Radical scavenging properties of polyamines. *Phytochemistry*. **25:** 367-371.

Erickson, V. J., Mandel, N. L. and Sorensen, F. C. 2004. Landscape patterns of phenotypic variation and population structuring in a selfing grass, *Elymus glaucus* (blue wildrye). *Canadian J. Botany*. **82:** 1776-1789.

Everard, J. D., Gucci, R., Kann S. C., Flore, J. A. and Loescher, W. H. 1994. Gas exchange and carbon partitioning in the leaves of celery (*Apium graveolens* L.) at various levels of root zone salinity. *Plant Physiology*. **106:** 281-292.

Fender, D. 2006. Urban perennial grasses in times of a water crisis: benefits and concerns. Council for Agricultural Science and Technology (CAST). Water quality & quantity issues for turfgrasses in urban landscapes, Las Vegas, NV.

Fu, J., Fry, J. and Huang, B. 2005. Minimum water requirements of four turfgrasses in transition zone. *Hort Science*. **39:** 1740-1749.

Fuente, V. and Ortunez, E. 2001. Festuca sect. Eskia (Poaceae) in the Iberian Peninsula. Folia Geo. *Botanica*. **36:** 385-421.

Harris, C. E. and Tullberg, J. N. 1980. Pathways of water loss from legumes and grasses cut for conservation. *Grass Forage Science*. **35:** 1-11.

Huang, B., Duncan, R. R. and Carrow, R. N. 1997. Drought-resistance mechanisms of seven warm-season turf grasses under surface soil drying. II. Root Aspects. *Crop Science*. **37:** 1863-1869.

Javis, P. G. and McNaughton, K. G. 1986. Stomatal control of transpiration: Scaling up from leaf to region. *Adv. Ecol. Res*. **15:** 1-49.

Jaleel, C. A., Sankar, B., Murali, P. V., Gomathinayagam, M., Lakshmanan, G. M. A. and Panneerselvam, R. 2008. Water deficit stress effects on reactive oxygen metabolism in *Catharanthus roseus*; impacts on ajmalicine accumulation. *Colloids Surf. B. Biointerfaces*, **62:** 105-111.

Johnson, G. V. 1973. Simple procedure for quantitative analysis of turf grass color. *Agronomy J.* **66:** 457-459.

Gorham, J., Jones, R. G. W. and McDonnell, E. 1985. Some mechanisms of salt tolerance in crop plants. *Plant and Soil*. **89(1-3):** 15-40.

Judziewicz, E. J. and Clark, L. G. 1993. The South-American species of Arthrostylidium (Poaceae, Bambusoideae, Bambuseae). *Systematic Botany*. **15:** 80-99.

Kallenbach, R. L. 1914. *Growth of pasture plants.* Missouri University Extension Publications. *Chapter III.* M182. pp. 1-4.

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. and Beard, J. B. 1988. Comparative turfgrass evapotranspiration rates and associated plant morphological characteristics. *Crop Science.* **28:** 328-331.

King, K. and Balogh, J. C. 2006. Nutrient and pesticide transport in surface runoff from perennial grasses in the urban landscape. Council for Agricultural Science and Technology (CAST). *Water Quality & Quantity Issues for Turfgrasses in Urban Landscapes.*

Korzun, V., Malyshev, S., Voylokov, A. and Borner, A. 1997. RFLP-based mapping of three mutant loci in rice (Secale cereale) and their relation to homoeologous loci within the Gramineae. *Theoretical and Applied Genetics.* **95:** 468-473.

Kozlowski, T. T. and Pallardy, S. G. 1997. Physiology of woody plants, Academic Press, San Diego, CA. pp. 25-26.

Lawlor, D. W. 1995. The effects of water deficits on photosynthesis. In: N. Smirnoff (eds.) Environment and plant metabolism: flexibility and acclimation. *BIOS Scientific Publishers Limited. Oxford, UK.*

Lee, G. J., Carrow, R. N. and Duncan, R. R. 2004. Salinity tolerance of selected seashore paspalums and Bermuda grasses: root and verdure responses and criteria. *Hort Science.* **39(2):** 1136-1142.

Levitt, J. B. 1972. Responses of plants to environmental stresses. *Academic Press,* New York.

Lin, Y., Deng, X. P., Kwak, S. S. *et al.* 2006. Enhanced drought tolerance in transgenic sweetpotato expressing both Cu/Zn superoxide dismutase and ascorbate peroxidase. *J. Plant Physiology and Molecular Biology.* **32:** 451-457.

Mckersie, B. D. and Leshem, Y. Y. 1994. Stress and stress coping in cultivated plants. *Klumer Academic Publishers, Netherlands.* p. 256.

Moreno, M. A., Harper, L. C., Krueger, R. W., Dellaporta, S.L. and Freeling, M. 1997. Ligule less encodes a nuclear-localized protein required for induction of ligules and auricles during maize leaf organogenesis. *Genes and Development.* **11:** 616-628.

Moradi, F. and Ismail, A. M. Responses of photosynthesis, chlorophyll fluorescence and ROS-scavenging systems to salt stress during seedling and reproductive stages in rice. 2007. *Annals of Botany.* **99(6):** 1161-1173.

Morris, K. N. and Shearman, R. C. 2000. The National Turfgrass Evaluation program (NTEP): assessing new and improved turfgrasses. *Diversity.* **16(2):** 19-22.

Nagar, S. Ajay arora, Singh, V. P, Ramakrishnan, S., Deepika, K., Umesh, Shailesh kumar and Saini, R. P. 2015. Effect of cytokinin analogues on cytokinin metabolism and stress responsive genes under osmotic stress in Wheat. *The Ecoscan.* **10(1):** 67-72.

Panse, V. G. and Sukhatme, P. V. 1985. In: Statistical methods for Agricultural Workers. 4th Ed. *ICAR.* New Delhi.

Parsons, L. R. 1982. Plant responses to water stress. In: Breeding plants for less favorable environments. (Eds.). M.N. Christiansen and C.F. Lewis. John Wiley and Sons, New York, pp. 175-192.

Patton, A. J. and Boyd, J. W. 2008. Choosing a grass for Arkansas Lawn. Appl. Turfgrass Sci., doi: 10.1094/ATS2008-2112-01-MD.

Pessarakli, M. and Kopec, D. M. 2009. Screening various ryegrass cultivars for salt stress tolerance. *J. Food, Agriculture and Environment.* **7(34):** 739-743.

Petit, J. R. Jouzel, J. and Raynaud, D. *et al.* 1999. Climate and atmospheric history of the past 420,000 years from the Vostokice core, Antarctica, *Nature.* **399:** 429-436.

Philipson, W. R. 1935. The Development and Morphology of the Ligule in Grasses. *New Phytology.* **34(4):** 310-325.

Sairam, R. K., Deshmukh, P. S. and Shukla, D. S. 1997. Tolerance to drought and temperature stress in relation to increased antioxidant enzyme activity in wheat. *J. Agron. Crop. Sci.* **178:** 171-177.

Salisbury, E. J. 1927. On the causes and ecological significance of stomata frequency with special reference to the woodland flora. *Phil. Trans. Roy. Soc. 21B:* 1065.

Shearman, R. C. 1989. Perennial ryegrass cultivar evapotranspiration rates. *Hort Science.* **24:** 767-769.

Singh, A. K., Singh S. K., Garg, H. S., Kumar R.,1 and Choudhary R. 2014. Assessment ofrelationships and variability of morpho physiological characters in bread wheat (*Triticum aestivum* L.) under drought stress and irrigated conditions. *The Ecoscan.* **9(2):** 473-484.

Smirnoff, N. and Cumbes, G. J. 1989. Hydroxyl radical scavenging activity of compatible solutes. *Photochemistry.* **28:** 1057-1060.

Stewart, J. R., Kjelgren, R., Johnson, P. G. and Kuhns, M. R. 2005. Growth and water relations of little leaf linden trees established in irrigated buffalo grass and Kentucky bluegrass. *Hort Science.* **40(5):**1529-1533.

Turgeon, A. J. 2002. Turfgrass management. *Fifth Edition. Prentice-Hall, Upper Saddle, NJ.*

Turner, N. C., Begg, J. E., Rawson, H. M., English, S. D. and Hearn, A. B. 1978. Agronomic and physiological responses of soybean and sorghum crops to water deficits. Components of leaf water potential, leaf conductance, $14CO_2$ photosynthesis, and adaptation to water deficit. *Australian J. Plant Physiology.* **5:** 179-194.

Verslues, P. E., Ober, E. S. and Sharp, R. E. 1998. Root growth and oxygen relations at low water potentials. Impact of oxygen availability in polyethylene glycol solutions. *Plant Physiology.* **116:** 1403-1412.

Watschke, T. L., Prinster, M. G. and Brenninger, J. M. 1992. Plant growth regulators and turfgrass management, In: Waddington, D.V., Carrow, R.N. and Shearman, R.C. (eds.). *Turfgrass Am. Soc. Agron. Monogr.* **32:** 557-558.

Weatherly, P. E. 1950. Studies in the water relation of cotton. 1. The field measurement of water deficits in leaves. *New Phytology.* **49:** 81-97.

Yoshida, S., Forno, D. A. and Cock, J. H. 1971. In: Laboratory manual for physiological studies of rice. *IRRI, Philippines.* pp. 36-37.

Zivcak, M., Brestic, M., Olsovska, K. and Slamka, P. 2008. Performance index as a sensitive indicator of water stress in *Triticum aestivum* L. *Plant Soil Environ.* **54:** 133-138.

Zuloaga, F. O., Morrone, O., Vega, A. S. and Giussani, L. M. 1998. Revision and cladistics analysis of Steinchisma (Poaceae: Panicoideae, Paniceae). *Ann. Missouri Bot. Gard.* **85(4):** 631-656.

Zhang, Y., Kadota, T. Ohata, T. and Oyunbaatar, D. 2007. Environmental controls on evapotranspiration from sparse grassland in Mongolia. *Hydrol. Process.* **21:** 2016-2027.