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Growth and physiological potential of various turf grass species under graded shade levels

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ABSTRACT

An study was carried out to evaluate the effects of graded shade levels on the growth and quality of turf grass species *Cynodon dactylon* (Bermuda grass), *Zoysia matrella* (Manilla grass), *Stenotaphrum secundatum* (St. Augustine grass), *Paspalum notatum* (Bahia grass), *Paspalum vaginatum* (Seashore Paspalum), *Dactyloctenium aegyptium* (Crowfoot grass), *Axonopus affinis* (Mat grass/Carpet grass) and *Eremochloa ophiuroides* (Centipede grass). These species grown under shade nets with different shading intensity of 25%, 50%, and 75% along with control (without shade net) were investigated at Division of Floriculture and Landscaping, IARI, New Delhi during 2017–19. Among the all species, Crowfoot grass and Zoysia found good under reduced irradiance conditionas compared to open conditions, while, St. Augustine, Bahia and Seashore Paspalum performed well from 25–50% reduced irradiance level but these were best under open conditions. Performance of Bermuda grass, Carpet grass and Centipede were not satisfactory under reduced irradiance level.

Keywords: Light intensity, Shade level, Turf grass

Growing turf grasses have become a big enterprise owing to the great demand for the establishment of lawns since well-established lawns are the continuous source of pleasure and serenity (Nadeem *et al*. 2012). In modern sport stadiums, reduction of photosynthetic active radiation influences durability and performance of a turf surface (Baker 1995). Associated with reduced irradiance, frequently higher relative humidity, decreased air movement, temperature fluctuations and drought stress (when shade is caused by trees) occur (Bell and Danneberger 1999). Together with reduced levels of irradiance these altered micro-environmental factors influence morphological and physiological plant responses (Beard 1997). With increased shade, a reduction in tiller density, leaf area index, dry weight, quantity of clipped material, and degree of coverage was observed in different species (Gaussoin *et al*. 1988) Furthermore, chlorophyll and carotenoid contents changed and root density decreased (Newell *et al*. 1999). At low irradiance, reduction in net photosynthesis and dark respiration, lower light saturation levels and decreased light compensation points are frequently observed in grasses (Allard *et al*. 1991). Response of turf grasses under shade has been well characterized in many tropical turfgrass species, e.g. Zoysia (Qian and Engelke 1999), Seashore Paspalum (Jiang *et al*. 2004) and St. Augustine grass (Trenholm and Nagata 2005). Development of new cultivars with superior shade adaptation is one of the challenges for breeders in future. Good management of a turf surface, choice of the right grass species can overcome problems related with shade. Therefore, the objective of this experiment was to determine the effects of graded shade levels on growth and quality of turf grasses and to find out suitable turf grasses for different shady areas.

MATERIALS AND METHODS

An experiment was carried out to evaluate the effects of graded shade levels (open, 25%, 50% and 75%) on the growth and quality of eight turf grass species *Cynodon dactylon* (Bermuda grass), *Zoysia matrella* (Manilla grass), *Stenotaphrum secundatum* (St. Augustine grass), *Paspalum notatum* (Bahia grass), *Paspalum vaginatum* (Seashore Paspalum), *Dactyloctenium aegyptium* (Crowfoot grass), *Axonopus affinis* (Mat grass/Carpet grass) and *Eremochloa ophiuroides* (Centipede grass) at Division of Floriculture and Landscaping IARI, New Delhi. Plastic pots (40 cm × 15 cm) were filled up with a mixture of soil, sand, and vermicompost (2:1:1). The native mixture was washed off the sods, and the sods were then transplanted into the plastic pots and grown for 12 weeks under normal irrigation to achieve full growth. Recommended agronomic practices like mowing, weeding and watering were followed uniformly for

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all the treatments. Recommended dose of fertilizer was also applied uniformly for all the treatments. After transplanting, pots kept under different graded UV Stabilized shade nets defined as treatments, viz. 0% (T_0, open sunlight), 25% (T_1), 50% (T_2), and 75% (T_3). The shade level was determined from percent reduction in light intensity from mid-day light condition (1300-1400 hr, light intensity ranging from 500-2500 mol/m^2/s). Shoot fresh weight (g), shoot dry weight (g), root fresh weight (g), root dry weight (g), total chlorophyll content, photosynthesis rate, transpiration rate, stomatal conductance were recorded three months after planting for all the treatments.The experiment was arranged in completely randomized design with three replications and analysed by using OPSTAT statistical software.

RESULTS AND DISCUSSION

Shoot fresh and dry weight (gm/100 cm^2): It is evident from the data (Table 1) that the effect of treatments, species and interaction of graded shade levels and species had significant effect on shoot fresh and dry weight (g/100 cm^2). Regardless of species, maximum shoot fresh weight was observed in treatment T_0, i.e. open conditions (34.09 g/100 cm^2), similarly, dry weight of shoot found maximum in open conditions (11.36 g/100 cm^2), i.e. in T_0. Minimum shoot fresh and dry weight were observed in treatment T_3 (16.22 and 5.40 g/100 cm^2). Among the species of turf grasses maximum shoot fresh and dry weight was found in Manila grass (34.73 and 11.57 g/100 cm^2), i.e. *Zoysia matrella,* while, minimum was observed in Carpet grass (11.52 and 3.84g/100cm^2), i.e. *Axonopu saffinis.* Perusal of data in Table 3 showed that interaction among turf grass species and graded shade levels on shoot fresh and dry weight resulted and were ranked according to percent increase in the shade level as Crow foot grass performed well and recorded maximum shoot fresh and dry weight (31.43 and 10.48 g/100 cm^2) at 50% shady condition followed by Manila grass which performed well at 25% shady situation (56.17 and 18.72 g/100 cm^2 shoot fresh and dry weight) as compared to open while St. Augustine, Bahia grass and Seashore Paspalum also gave better results under up to 50% graded shade level but they were best under open conditions. Moreover, most of the turf grass species have maximum shoot density in open conditions and performance of Bermuda grass, Centipede and Carpet grass were not satisfactory under reduced irradiance level.The above results are in accordance with findings of researchers (Jiang *et al.* 2004, Bunnell *et al*. 2005) where shade limited the growth of warm season grasses like Bermuda grass (*Cynodon dactylon*). The fluctuations in the morphological traits could be attributed to response of grass against low intensities of light (Wherley *et al*. 2005) which in turn affected the nutritional status, hormonal level, and photosynthesis and anti-oxidation activity of the cells (Xu *et al*. 2011). Moreover, many researchers argued that the roots play an important role in forming the shoot weight (Gibson 2009, Younis *et al*. 2013). Under high shade levels, shoot fresh and dry weight was less due to thinner and elongated shoot

Table 1 Effect of graded shade level on shoot fresh weight and dry weight (g/100 cm^2) of different turf grass species

Treatment	Shoot fresh weight (g/100 cm^2)								Shoot dry weight (g/100 cm^2)							
	SA	C F	Be	M	Ba	SP	Ce	Ca	Mean A	SA	C	Be	M	Ba	SP	Ce	Ca	Mean A
$T_{0\ (open)}$	35.70	16.53	45.17	23.57	30.67	42.23	54.53	24.30	34.09	11.89	5.51	15.05	7.85	10.22	14.07	18.1	8.10	11.36
$T_{1\ (25\%)}$	34.10	17.53	40.90	56.17	29.20	39.47	28.87	10.00	32.03	11.36	5.84	13.63	18.72	9.73	13.15	9.62	3.33	10.67
$T_{2\ (50\%)}$	31.93	31.43	20.83	41.50	27.67	31.87	23.80	6.43	26.93	10.65	10.48	6.94	13.83	9.22	10.62	7.93	2.14	8.98
$T_{3\ (75\%)}$	26.00	20.47	13.73	17.67	18.07	18.30	10.17	5.33	16.22	8.63	6.84	4.57	5.88	6.02	6.09	3.39	1.77	5.40
Mean B	31.93	21.49	30.16	34.73	26.40	32.97	29.34	11.52		10.63	7.17	10.05	11.57	8.80	10.98	9.78	3.84	
CD (P=0.05) Factor (A)	2.37									0.79								
Factor (B)	3.35									1.12								
Factor (A × B)	6.70									2.23								

SA, St. Augustine; CF, Crow foot; Be, Bermuda; M, Manila; Ba, Bahia; SP, Seashore Paspalum; Ce, Centipede, Ca, Carpet.

Table 2 Effect of graded shade level on root fresh weight and dry weight (g/100 cm^2) of different turf grass species

	Root fresh weight (g/100 cm^2)									Root dry weight (g/100 cm^2)								
Treatment	SA	C F	Be	M	Ba	SP	Ce	Ca	Mean A	SA	C F	Be	M	Ba	SP	Ce	Ca	Mean A
$T_{0\ (open)}$	70.90	22.43	56.80	33.33	74.30	37.20	35.17	15.43	43.20	23.63	7.47	18.93	11.11	24.76	12.40	11.72	5.14	14.40
$T_{1\ (25\%)}$	67.50	23.93	49.83	60.83	72.00	34.63	21.67	4.50	41.86	22.50	7.97	17.44	20.27	23.99	11.54	7.22	1.50	14.05
$T_{2\ (50\%)}$	66.50	41.50	24.30	46.40	71.33	29.00	15.33	2.70	37.13	22.16	13.83	8.10	15.46	23.77	9.66	5.11	0.90	12.38
$T_{3\ (75\%)}$	61.57	30.80	13.60	21.27	62.50	20.10	6.20	2.13	27.27	20.52	10.28	4.54	7.08	20.83	6.70	2.06	0.72	9.09
Mean B	66.62	29.67	36.13	40.46	70.03	30.23	19.59	6.19		22.20	9.89	12.25	13.48	23.34	10.07	6.53	2.06	
CD (P=0.05) Factor (A)	1.79									0.60								
Factor (B)	2.53									0.85								
Factor (A×B)	5.07									1.69								

SA, St. Augustine; CF, Crow foot; Be, Bermuda; M, Manila; Ba, Bahia; SP, Seashore Paspalum; Ce, Centipede, Ca, Carpet.

Table 3 Effect of graded shade level on total chlorophyll content (mg/g fw) and photosynthesis rate (µmol $CO_2/m^2/s$) of different turf grass species

	Total chlorophyll content (mg/gfw)									Photosynthesis rate (µmol $CO_2/m^2/s$)								
Treatment	SA	C F	Be	M	Ba	SP	Ce	Ca	Mean A	SA	C F	Be	M	Ba	SP	Ce	Ca	Mean A
$T_{0\ (open)}$	1.54	1.78	3.33	2.65	3.11	1.45	2.23	2.01	2.26	10.06	3.72	5.01	2.88	12.65	6.14	7.49	10.94	7.36
$T_{1\ (25\%)}$	3.83	2.40	4.81	3.91	2.78	3.19	3.34	4.02	3.54	8.84	4.84	4.22	5.23	11.69	5.37	6.02	6.51	6.59
$T_{2\ (50\%)}$	3.53	2.97	4.26	2.98	2.70	2.78	3.20	3.87	3.29	7.60	11.64	3.84	4.31	9.76	5.07	3.63	4.50	6.30
$T_{3\ (75\%)}$	3.48	2.78	4.00	2.93	2.52	2.72	2.94	1.97	2.92	6.47	7.51	2.32	2.50	9.34	3.94	3.06	2.80	4.74
Mean B	3.10	2.49	4.10	3.12	2.78	2.54	2.93	2.97		8.24	6.93	3.85	3.73	10.86	5.13	5.05	6.19	
CD (P=0.05) Factor (A)	0.02									0.29								
Factor (B)	0.03									0.42								
Factor (A×B)	0.06									0.83								

SA, St. Augustine; CF, Crow foot; Be, Bermuda; M, Manila; Ba, Bahia; SP, Seashore Paspalum; Ce, Centipede, Ca, Carpet.

growth of the grasses (Bar and Schulz 1995).

Root fresh and dry weight (g/100 cm^2): It is clear from the data (Table 2) that the effect of treatment, species and interaction was found to be significant with respect to root fresh and dry weight (g/100 cm^2). Root fresh and dry weight of all turf grasses species was significantly influenced by graded shade levels. As shade level per cent increased root fresh and dry weight reduced in most of the species of turf grasses. Among the different turf grass species, it was found that the maximum root fresh and dry weight was recorded in Bahia grass (70.03 and 23.34 g/100 cm^2, respectively), i.e. *Paspalum notatum* and minimum was observed in Carpet grass (6.19 and 2.06 g/100 cm^2), i.e. *Axonopus affinis*. Among the graded shade level, it was observed that maximum root fresh and dry weight (g/100 cm^2) recorded in treatment T_0 (43.20 and 14.40 g/100 cm^2) while minimum was found in T_3 (27.27 and 9.09 g/100 cm^2).Interaction data about root fresh and dry weight (g/100 cm^2) between turf grass species and graded shade levels revealed that Crow foot grass recorded maximum root fresh and dry weight (41.50 and 13.83 g/100 cm^2) at 50% reduced irradiance level followed by Manila grass at 25% reduce irradiance level (60.83 and 20.27 g/100 cm^2).

Root dry weight may be dependent on growth of the grass and moisture percentage in that grass species. Similar observation was recorded by Tegg and Lane (2004) that there was reduction in turf grass growth rate and quality of the grass grown under reduced light intensity environments. On the other hand, our results showed that Crow foot grass which performed best at 50% and Zoysia was best at 25% shady condition, where, St. Augustine Bahia and Seashore Paspalum were performed well up to 50% reduced irradiance level. These findings are in accordance with Mohanty and Rai (2008) and Trenholm and Nagata (2005).

Total chlorophyll content (mg/g fw): Data (Table 3) indicated that the effect of treatment, species and interaction was found to be significant with respect to total chlorophyll content. Chlorophyll content of all turf grass species was significantly influenced by different shade levels. Among the different turf grass species, maximum total chlorophyll content was recorded in Bermuda grass (4.10 mg/g fw), i.e. *Cynodon dactylon* and minimum in Crow foot grass (2.49 mg/g fw), i.e. *Dactyloctenium aegyptium*. Regardless of species, maximum total chlorophyll content was observed in treatment T_1 (3.54 mg/g fw), i.e. 25% shade level and minimum in treatment T_0 (2.26 mg/g fw) under open condition. Perusal of data in Table 7 and Fig 2 showed that interaction among turf grass species and graded shade levels on total chlorophyll content resulted that the among all the species of turf grass in open condition total chlorophyll content was low except Bahia grass (3.11 mg/g fw) and at 25% shade level it was recorded highest for most of the species except Crow foot grass which had recorded maximum at 50% shade level (2.97 mg/g fw) but after this level at 75% it was in reducing pattern. It is reported by several researchers that shading causes increase in chlorophyll concentration. Peacock and Dudeck (1981) reported that turf grasses under shade have increased chlorophyll concentrations per fresh weight rather than per unit area. However, increase in chlorophyll concentration is not necessarily a shade tolerant character.

Photosynthesis rate (µmol CO_2/m^2/s): Data (Table 3) showed that the effect of treatment, species and interaction was significant with respect to photosynthesis rate (µmol CO_2/m^2/s). Photosynthesis rate of all turf grass species was significantly influenced by graded shade level. Among the different turf grass species, it was found that the maximum photosynthesis rate observed in Bahia grass (10.86 µmol CO_2/m^2/s), i.e. *Paspalum notatum* and miniumum was found in Manila grass (3.73 µmol CO_2/m^2/s), i.e. *Zoysia matrella*. Among the graded shade level, maximum photosynthesis rate recorded in treatment T_0 (7.36 µmol CO_2/m^2/s) in open conditions and minimum in treatment T_3 (4.74 µmol CO_2/m^2/s) at 75% shade level. Perusal of data in Table 8 showed that interaction among turf grass species and graded shade levels on total photosynthesis rate resulted that in Crow foot grass it was found maximum at 50% shade level (11.64 µmol CO_2/m^2/s) while in Manila grass at 25% shade level it was recorded maximum (5.23 µmol CO_2/m^2/s). PAR levels were reduced under shade nets of different shade levels (Middleton and Mc Waters 2002). The distinct morphological changes include increased leaf length (Peterson *et al.* 2014), shoot elongation and increased leaf area. The significant physiological shade responses of turf largely involve reduction of clipping weight (Tegg and Lane 2004) and increased in chlorophyll content (Beard 1973). In addition, leaf senescence was induced under severe shade conditions when plants were experiencing a net negative carbon balance, i.e. increased respiration over

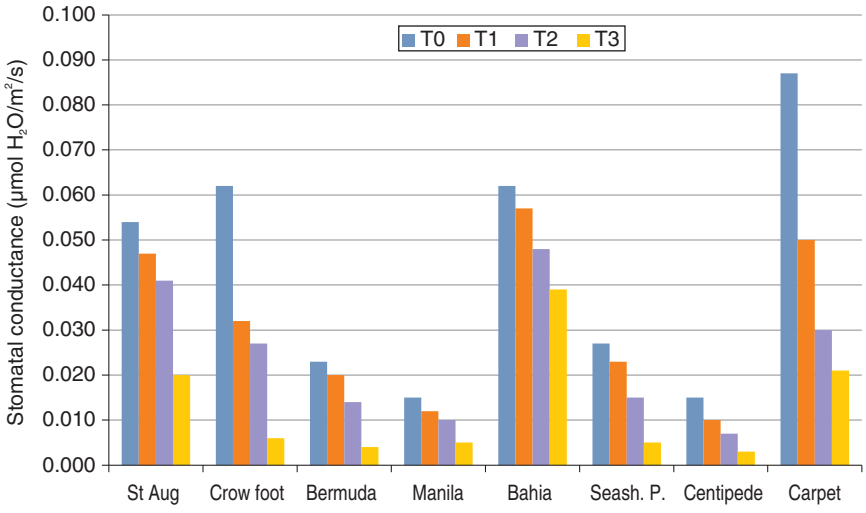

Fig 1 Effect of graded shade level on stomatal conductance (µmol H_2O/m^2/s) of different turf grass species.

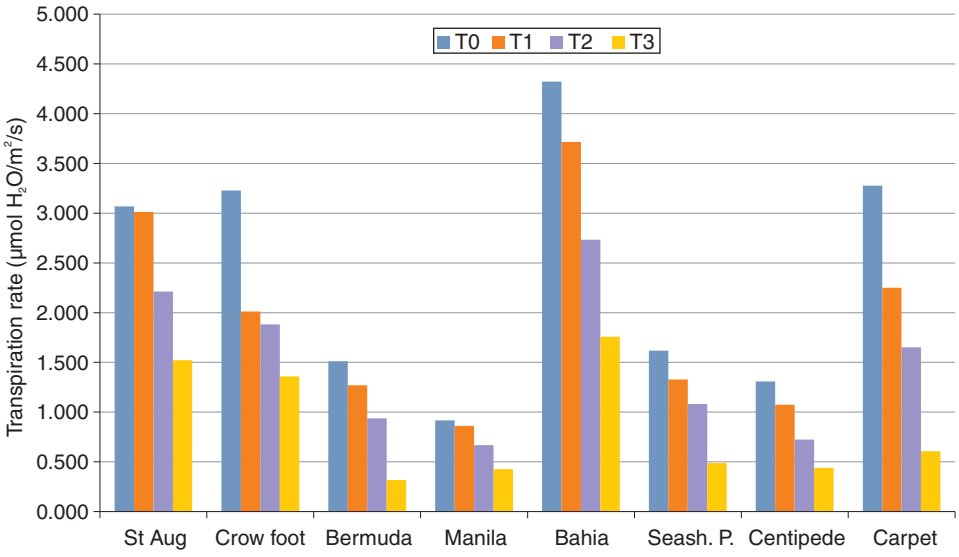

Fig 2 Effect of graded shade level on transpiration rate (µmol $H_2O/m^2/s$) of different turf grass species

photosynthesis (Brouwer *et al.* 2012).

Our study indicated that Capet grass, Centipede grass and Bermuda photosynthesis reduces drastically as irradiance level decreases. Similar observation was also recorded by Van *et al.* (1999). Bradley *et al*. (2009) reported that shading reduced photosynthesis and resulted in reduced turf grass aesthetic quality in Zoysia grass species, while in case of St. Augustine, Bahia and Seashore Paspalum results showed gradual reduction in photosynthesis activity. However,Crowfoot grass performed best at 50% shade and Zoysia recorded highest photosynthesis activity at 25% shade level. Under high irradiance, however, the photosynthetic apparatus absorbs excessive light energy, resulting in the inactivation or impairment of the chlorophyll containing reaction centers of the chloroplasts (Bertaminia *et al*. 2006).

Stomatal conductance (µmol $H_2O/m^2/s$) : The data for stomatal conductance (µmol $H_2O/m^2/s$) was analysed (Fig 1). Stomatal conductance of all grasses decreased with increasing graded shade levels. Regardless of shade level, maximum stomatal conductance was recorded in Bahia grass (0.052 µmol $H_2O/m^2/$) and minimum in Centipede grass (0.009 µmol $H_2O/m^2/s$). Among the treatments of graded shade level, stomatal conductance recorded maximum at T_0 (0.043 µmol $H_2O/m^2/s$) and minimum was recorded at T_3 (0.013 µmol $H_2O/m^2/s$) 75% shade net conditions. The interaction data showed that the stomatal conductance of all the species significantly decreasing in respect to the increasing shade levels. All the grasses exhibited higher stomatal conductance at control, i.e. in open conditions but it decreased as irradiance level reduced. Physiological processes that are affected under low light levels are stomatal conductance, transpiration rate (Givnish 1986).According to Allard *et al*. (1991) turf grasses growing under low light intensities have larger leaves in order to compensate lower carbon dioxide exchange rates (CER) per unit area.

Transpiration rate (µmol $H_2O/m^2/s$): The data for transpiration rate (µmol $H_2O/m^2/s$) was analysed (Fig 2). Transpiration rate of all grasses decreased with increasing graded shade levels from open to 75% shade net conditions. Regardless of shade level, maximum transpiration rate was recorded in Bahia grass (3.133 µmol $H_2O/m^2/$) and minimum in Manila grass (0.718 µmol $H_2O/m^2/s$). Among the treatments of graded shade level, transpiration rate recorded maximum at T_0 (2.406 µmol $H_2O/m^2/s$) in open conditions and minimum at T_3 (0.864 µmol $H_2O/m^2/s$) 75% shade net conditions. The interaction data showed that the transpiration rate of all the species significantly decreasing in respect to the increasing shade levels. All the grasses exhibited higher transpiration at control, i.e. in open conditions but it decreased as irradiance level reduced upto 75% shade net conditions. It is due to the interruption of direct light and leaf surface area of grasses. Overall the gaseous exchange was found to be higher under white open condition for all the turf grass species. Boardman (1977) summarized the responses of plants under shade that are commonly found in turf grasses.

The effects of shade on turf grasses result in numerous visual, physiological, and morphological responses. Growing turf in shade requires certain cultural management practices that are different from growing turf in the sun. On the basis of the performance of different turf grass species, it was concluded that Crow foot grass and Manila grass have ability to grow better under shady conditions, i.e. 50% and 25% shade level, respectively. Moreover, St. Augustine, Bahia and Seashore Paspalum were found suitable up to 25–50% reduced irradiance level but their performance was better under open conditions. Bermuda grass, carpet grass and centipede have poor shade adaptability. In addition to this, Crow foot grass and Manila grass making it an excellent turf grasses for lawns where there may be variations in the amount of sunlight available.

REFERENCES

Allard G, Nelson C J and Pallardy S G .1991. Shade effects on growth of tall fescue: II Leaf gas exchange characteristics. *Crop Science* **31**: 167–72.

Baker S W. 1995. The effects of shade and changes in microclimate on the quality of turf at professional football clubs. I. Questionnaire survey. *Journal of Sports Turf Research Institute*. **71**: 66–74.

Bar D and Schulz H. 1995. Effect of shade on turf grasses. Rasen-*Turf-Gazon* **26**(2): 48–55.

Beard J B. 1997. Shade stresses and adaptation mechanisms of turf grasses. *International Turf Grass Society Research Journal* **8**: 1186–95.

Bell G E and Danneberger T K. 1999. Temporal shade on Creeping bent grass turf. *Crop Science* **39**:1142-1146.

Bertaminia M, Muthuchelianb K, Rubinigga M, Zorera R, Velascoa R and Nedunchezhiana N. 2006. Low-night temperature increased the photoinhibition of photosynthesis in grapevine (*Vitis vinifera* L. cv. Riesling) leaves. *Environmental and Experimental Botany* **57**(1–2): 25–31.

Boardman N K .1977. Comparative photosynthesis of sun and shade plants. *Annual review Plant Physiology* **28**: 355–77.

Bradley S Sladek, Gerald M Henry and Dick L Auld. 2009. Evaluation of zoysia grass genotypes for shade tolerance. *Hort Science* **44**(5): 1447–47.

Brouwer B, Ziolkowska A, Bagard M, Keech O and Gardeström P. 2012. The impact of light intensity on shade-induced leaf senescence. *Plant Cell Environment* **35**: 1084–98.

Bunnell B T, McCarty L B and Bridges W C F. 2005. 'Tifeagle' Bermuda grass response to growth factors and mowing height when grown at various hours of sunlight. *Crop Science* **45**: 575–81.

Gaussoin R E, Baltensperger A A and Coffey B N. 1988. Response of 32 Bermuda grass clones to reduced light intensity. *HortScience* **23**: 178–79.

Gibson D J. 2009. *Grasses and Grassland Ecology*.Oxford University Press.

Givnish T J. 1986. Optimal stomatal conductance, allocation of energy between leaves and roots, and the marginal cost of transpiration. Cambridge University Press: Cambridge, pp 171–13.

Jiang Y W, Duncan, R R and Carrow R N. 2004.Assessment of low light tolerance of Seashore Paspalum and Bermuda grass. *Crop Science* **44**: 587–94.

Middleton S and McWaters A. 2002. Hail netting of apple orchards – Australian Experience. *Compact Fruit Tree* **35**: 51–55.

Mohanty C R and Rai B G M. 2008. Relative performance of lawn grasses under different light intensities. *Journal of Ornamental Horticulture* **11**(4): 281–86.

Nadeem M, Younis A, Riaz A and Hameed M. 2012. Growth response of some cultivars of Bermuda grass (*Cyanodon dactylon* L.) to salt stress. *Pakistan Journal of Botany* **44**: 1347–50.

Newell A J, Hart-Woods J C and Wood A D. 1999. Effects of four different levels of shade on the performance of three grass mixtures for use in lawn tennis courts. *Journal Turf Grass Science* **75**: 82–88.

Peacock C H and DudeckA E. 1981. Effects of shade on morphological and physiological parameters on St. Augustine grass cultivars. *(In) Proceeding of 4th International Turf Grass Research Conference*. 493–500.

Peterson K W, Fry J D and Bremer D J. 2014. Growth responses of *Zoysia* spp. under tree shade in the Midwestern United States. *HortScience* **49**: 1444–48.

Qian Y L and Engelke M C. 1999. Infuence of trinexapac-ethyl on Diamond zoysia grass in a shaded environment. *Crop Science* **39**: 202–08.

Tegg and Lane 2004.A comparison of the performance and growth of a range of turf grass species under shade. *Australian Journal of Experimental Agriculture* **4**4(3): 353–58.

Trenholm L E and Nagata R T. 2005. Shade tolerance of St. Augustine grass cultivars. *Hort Technology* **15**: 267–72.

Van Huylenbroeck, J M P Lootens and E Van Bockstaele 1999 Photosynthetic characteristics of perennial ryegrass and red fescue turf-grass cultivars.

Wherley B G, Gardner D S, and Metzger J D. 2005. Tall fescue photomorphogenesis as influenced by changes in the spectral composition and light intensity. *Crop Science* **45**: 562–68.

Xu Y, Chen H, Zhou H, Jin J and Hu T. 2011. Acclimation of morphology and physiology in turf grass to low light environment: A review. *African Journal of Biotechnology* **10**: 9737–42.

Younis A, Riaz A, Ikram S, Nawaz T, Hameed M, Fatima S, Batool R and Ahmad F. 2013. Salinity-induced structural and functional changes in three cultivars of *Alternanthra bettzikiana* (Regel) G. Nicholson. *Turkey Journal Agricultural Forestry* **37**: 674–68.