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Evaluation of warm season turfgrasses for various qualitative and quantitative traits under Gujarat agro-climatic conditions

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ABSTRACT

An experiment was carried out to evaluate different turfgrass species and varieties for the morphological characters under south Gujarat agro-climatic condition. Wide range of variation among the 13 genotypes of turfgrasses was recorded with respect to bio-agronomical and quality characteristics. Among the various characters, minimum days to 90 per cent establishment and deepest root were observed in *Cynodon dactylon* Local, which was at par with *C. dactylon* × *C. transvaalensis* Tifdwarf. Lowest canopy height, shortest average stolon internodal diameter, highest shoot density, narrowest leaf width and slowest VLGR were recorded in *Zoysia tenuifolia*. Maximum cumulative fresh clipping yield and minimum value of stolon internodal length were registered in Tifdwarf. *Z. tenuifolia*, *Z. matrella* and Tifdwarf showed very fine texture of leaves, whereas the latter also showed consistently good average turf quality rating and chlorophyll content in the whole period of experimentation. Under south Gujarat agro-climatic condition, *C. dactylon* L. × *C. transvaalensis* Tifdwarf performed best in most of turf quality parameters and can be subjected to further functional quality trials for sports and athletic turf.

Key words: Evaluation, Genotypes, Turfgrass, Turf quality

Turfgrasses consist of a remarkably diverse group of species which are selectively used on the basis of applications and/or climatic conditions (Janakiram and Namita 2014). Cultivated turfgrass is a pervasive feature of the urban landscape in the developed regions of the world. Turfgrasses are widely used in enhancing and maintaining the function and beauty of lawns, aesthetic fields, *etc.* all over the world.

Turfgrass provides at least three major benefits to human activities: functional, recreational and ornamental (Beard 1973, Christians 2004, Wiecko 2006, Turgeon 2008, Bell 2011, Janakiram *et al.* 2015). Since, wide variability occurs among commercial turfgrasses, the choice of species and/or variety should be taken in high consideration in accordance with the intended use as low maintenance turf, high maintenance sports turf, home lawn or public places, *etc.* Despite, cultural practices are very critical for turf performance, varietal selection adaptable to the particular area plays an important role.

The quality of a sports field surface as well as playability is determined by turfgrass species as well as varieties. Turfgrass growth, performance and quality are affected by many environmental factors prevailing locally. Therefore, evaluation for the suitability of turfgrass for a particular region will play a crucial role for their selection. This means, for one season a particular variety can give outstanding result but it may show poor performance in another season or year. No systematic work has been carried out on the aspect of turfgrass evaluation in Gujarat yet, therefore, the present investigation was undertaken to evaluate the different turfgrass genotypes with respect to various bio agronomical and qualitative traits for landscaping and sport's field.

MATERIALS AND METHODS

The experiment was carried out at Floriculture Research Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari during 2014-15. The Navsari comes under south Gujarat heavy rainfall zone-I, AES-III. The experiment was laid out in randomized block design with three replications. Only healthy uniform sprigs of 10-12 cm long stolons were planted at 5 cm × 5 cm spacing in gross plots having 1.5 m × 1.5 m size with net plots of 1.0 m × 1.0 m. Experimental material included seven *Cynodon dactylon* genotypes, one local selection of *C. dactylon* (unknown parentage), one *C. dactylon* × *C. transvaalenesis* Tifdwarf hybrid, two different species of *Zoysia,* viz. *Z. tenuifolia* and *Z. matrella*, and three other genera *Axonopus compressus*, *Stenotaphrum secundatum* and *Eremochola ophiuroides*. All the genotypes were maintained under uniform cultural conditions.

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For establishment rate, number of days was counted from transplanting till the genotypes covered 90 per cent of their respective net plots and averaged based on visual estimation. Plant characters related to crop production usually observed during plant growth are termed as bio-agronomic characters. Different bio-agronomic traits like canopy height (cm), vertical leaf growth rate (mm/d) (Veronesi *et al.* 1992), fresh clipping yield (g/m^2), stolon internodal length (cm), stolon diameter (mm) by digital vernier calliper, leaf length and turf quality rating for all the months, whereas leaf width (mm) (Veronesi *et al.* 1992), shoot density (count per 25 cm^2) (Janakiram and Namita 2014), root depth (cm), growth habit (Eggens 1981) were taken at the end of experiment as suggested. The monthly multiple rating system (density, texture, uniformity, colour and stress) were used to calculate the annual mean turf quality rating (scale of 1-9, where 9 = highest quality) for each individual genotype which was used to assess best quality. This method was given by National Turfgrass Evaluation Program, The Pennsylvania Turfgrass Council (Morris and Sherman, 2000). Total chlorophyll content in leaves was determined by DMSO (Dimethyl sulphoxide) method (Wellburn 1994) at the end of four different seasons, viz. summer (April-2014), monsoon (June-2014), post monsoon (October-2014) and winter (January-2015). The meteriological data of during experiment are also presented in Table 1 for better understanding. The data on various observations were recorded during the course of investigation were statistically analyzed using randomized block design described by Panse and Sukhatme (1967). The appropriate standard error of mean (SEm. ±) and the critical difference (CD) were calculated at 5 per cent level of probability.

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences among different genotypes for all bio-agronomic traits as well as turf quality. Visual qualities are actually founded on functional qualities and the functional quality of a turfgrass is determined solely by its vegetative plant part and its growth and development (Gobilik *et al.* 2013). Mean performance of the different genotypes revealed that no single genotype was superior for all traits as supported by Janakiram and Namita (2014).

Establishment is a process that is closely related to the speed of sprouting of buds on stolon, followed by growth and development. It relates to the vigour and adaptability of the grass genotype (Magni *et al.* 2014). It is perceptible from the data presented in Table 2 that significantly minimum days to 90 per cent establishment was recorded in *C. dactylon* Local (14.00 days) which was due to greater adaptability of native genotype. Potenza *et al.* (2014) also reported that regionally adapted native grass species are worth investigating due to their potential performance advantages and faster establishment. Mainly bermudagrass varieties hold major advantage over others with fast and very good establishment (Turgeon 2008). However, *Z. tenuifolia* showed slowest establishment (83.33 days) which is attributed to its slow growth rate (Turgeon 2008 and Harivandi 1984). These findings are in accordance with findings of Harivandi (1984), Severmutlu *et al.* (2011) for establishment rate. In the present study, *A. compressus* showed higher vigour and faster establishment rate than all other grasses used in the study. The reason can be attributed to its humid-tropical origin. The climate of Navsari is also typically tropical thus, the adaptation and growth was faster.

Canopy height measures the vertical growth of the turf

Table 1 Meteorological data during experimentation

Month	Max. temp (°C)	Min. temp. °C)	Average temp. °C)	RH (%)		Average RH (%)	Total rain-fall (mm)	Cloud cover (Oktas)	Cloud cover (Oktas)	Evaporation (mm/day)
	I	I		I	II			I	II	I
February -2014	29.0	14.5	21.7	79.0	34.1	56.5	0.0	0.3	0.3	4.4
March-2014	33.4	17.8	25.6	81.0	34.0	58.0	0.0	0.1	0.3	6.1
April-2014	35.4	22.2	28.8	86.0	42.0	64.0	0.0	0.5	0.0	6.7
May-2014	34.8	25.7	30.3	84.0	55.0	70.0	0.0	1.0	0.3	6.8
June-2014	33.7	27.9	30.8	80.5	63.6	72.1	1.2	3.3	1.9	8.7
July-2014	30.8	25.8	28.3	89.0	78.0	83.0	23.2	5.9	3.9	4.0
August-2014	30.3	25.1	27.7	93.0	80.0	86.0	10.5	5.2	4.5	3.0
September-2014	31.3	24.5	27.9	93.0	76.0	84.0	12.6	3.4	0.0	3.0
October-2014	35.9	22.4	29.2	83.0	43.0	63.0	0.0	0.4	0.5	4.5
November-2014	33.6	19.2	26.4	86.0	43.0	64.0	2.2	0.4	0.0	4.0
December-2014	30.4	14.0	22.2	73.0	40.0	57.0	0.0	0.1	0.0	3.0
January-2015	28.9	12.9	20.9	79.0	37.0	58.0	0.0	0.2	0.1	3.1
February-2015	30.9	14.1	22.5	83.0	39.0	61.0	0.0	0.0	0.0	4.0

*I : Observation taken at 7:30 am. *II: Observation taken at 2:30 am

Table 2 Performance of different turfgrass genotypes for various quantitative and qualitative traits

Genotype	Days to 90% establishment	Root depth (cm)	Shoot density (25 cm^2)	Leaf width (mm)	Leaf chlorophyll content (mg/g)				Growth habit
					Apr-14	Jul-14	Oct-14	Jan-15	
Cynodon dactylon var. Black Jack	18.33	23.00	26.74	2.35	2.24	2.20	1.23	1.26	Upright
C. dactylon. var. Bargusto	23.67	17.00	25.99	2.13	2.25	2.33	1.24	1.14	Upright
C. dactylon. var. Panama	38.00	15.33	30.92	2.27	2.23	2.29	2.27	2.31	Semi-prostrate
C. dactylon var. Palma	23.00	11.67	17.00	2.27	2.30	2.51	2.11	2.31	Upright
C. dactylon var. Panam	22.33	23.17	12.06	2.52	1.82	2.34	2.24	2.27	Upright
C. dactylon var. Selection 1	18.00	14.57	108.21	1.35	2.24	2.45	2.05	1.90	Semi-prostrate
C. dactylon var. Local	14.00	24.50	63.32	1.50	2.26	2.87	2.06	2.84	Prostrate
C. d. × *C. t.* var.Tifdwarf	16.33	9.67	174.25	1.17	2.79	3.30	2.65	2.59	Prostrate
Axonopus compressus	51.33	15.60	10.18	8.38	1.71	1.64	1.39	1.45	Prostrate
Zoysia tenuifolia	83.33	18.84	227.14	1.05	1.55	2.54	2.37	2.22	Semi-prostrate
Zoysia matrella	73.00	17.13	211.23	1.26	2.15	2.75	2.42	2.10	Semi-prostrate
Stenotaphrum secundatum	61.00	13.13	8.30	7.47	1.10	1.34	0.87	0.71	Prostrate
Eremochola ophiuroides	64.67	11.87	25.02	2.92	2.04	2.72	1.70	1.60	Prostrate
CD (P = 0.05)	6.76	4.22	12.18	0.57	0.29	0.25	0.29	0.16	
CV (%)	10.28	15.09	9.99	12.02	8.36	6.20	9.00	5.02	

(Turgeon 2008). Different grass genotypes have different predetermined heights on which they display best of their visual characteristics (Christians 2004). Genotypes with shorter canopy height are preferred over a time period by keeping acceptable visual and aesthetic parameters by requiring comparatively lesser number of mowing and low maintenance. As per Table 3, in all months, *Z. tenuifolia* (43.87 cm) recorded lowest cumulative canopy height followed by *Z. matrella* . The difference among the genotypes can be attributed to their genetic constitution. All genotypes attained greater canopy height in rainy season (July-September, 2014). In warm season grasses,

Table 3 Canopy height (cm) of various turfgrass genotypes during different sampling months.

Genotype	Year										Cumulative canopy height (cm)
	2014									2015	
	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	
Cynodon dactylon var. Black Jack	14.31	9.51	8.03	22.71	22.67	22.36	10.58	7.71	9.39	8.67	135.94
C. dactylon. var. Bargusto	7.83	6.46	9.34	11.22	11.52	11.00	8.81	6.21	6.58	5.84	84.81
C. dactylon. var. Panama	8.37	10.11	7.28	12.72	12.60	12.67	8.80	5.40	5.87	5.27	89.09
C. dactylon var. Palma	10.51	9.81	8.44	12.13	12.47	12.47	11.06	6.64	6.80	6.19	96.52
C. dactylon var. Panam	6.33	8.63	8.31	21.70	23.94	23.61	11.53	6.50	6.69	6.25	123.49
C. dactylon var. Selection 1	5.60	5.06	3.44	7.12	7.42	8.66	5.64	3.78	3.80	3.57	54.09
C. dactylon var. Local	3.54	5.16	3.87	7.83	7.19	7.27	4.79	5.08	5.08	3.95	53.76
C. d. × *C. t.* var. Tifdwarf	8.97	7.16	5.59	6.91	7.74	7.80	6.29	4.40	4.31	3.36	63.53
Axonopus compressus	3.68	5.72	4.62	11.11	12.96	11.97	5.87	6.23	6.21	4.62	72.99
Zoysia tenuifolia	3.41	3.56	4.59	5.78	6.09	5.93	4.52	3.31	3.34	3.34	43.87
Zoysia matrella	3.53	4.24	4.73	6.29	6.56	6.48	4.84	3.68	3.88	3.77	48.00
Stenotaphrum secundatum	4.74	6.02	5.44	6.31	6.18	6.12	5.18	3.37	4.57	3.99	51.92
Eremochola ophiuroides	6.08	7.23	6.43	14.17	14.69	14.46	8.54	6.20	6.60	6.60	91.00
CD (P = 0.05)	1.45	1.69	1.47	2.35	1.48	1.79	1.42	1.17	1.34	0.97	
CV (%)	12.86	14.71	14.16	12.39	7.53	9.16	11.37	13.17	14.10	11.41	

high relative humidity, moderate temperature and quality water of rain have its effect on biomass accumulation and growth (Bell 2011). It is clear from the data (Table 4) that slowest vertical leaf growth rate (VLGR) was recorded by *Z. tenuifolia* (0.05 mm/day) followed by *Z. matrella* (0.06 mm/day). When the temperature reduced in winter season (November-2014 to January-2015), all genotypes showed comparatively slow growth thus shorter canopy height. The reason behind this can be attributed to the genetic makeup of warm season grasses. As temperatures cools in winter, turfgrasses begin to harden off for the winter which means that they begin to prepare themselves to withstand temperatures that would normally be damaging (Bell 2011). As the winter approaches, both warm and cool season turfgrasses begin translocation of carbohydrates into their roots and stems thus, result into slower growth. In all seasons, VLGR followed same pattern as canopy height. This was also supported by findings of Leto *et al.* (2008). Harivandi (1984) also noticed that within a genus, a given grass variety may differ little from one another. It has to be noted that all the genotypes showed an increasing trend in growth related parameters like canopy height and growth rate during the monsoon season; this was due to greater availability of water for photosynthesis. The difference among canopy height and increase in culm length was attributed to the growth habit of genotypes as supported by Viggiani *et al.* (2015). A similar behaviour was also found by Ubendra *et al.* (2015) that a high influence of rainfall promoted the highest values of the growth related parameters.

Higher is the clipping yield better is the variety for suitability in high maintenance areas like golf greens of golf course and sports field, while the turf with high density and low cumulative fresh clipping yield is suitable for low maintenance areas such as home lawns, parks and public places or soil conservation. The results presented in Table 5 expressed consistently higher fresh clipping yield along with cumulative yields (April-January) in Tifdwarf (3492.98 g/m^2) and lowest clipping yield in *Z. tenuifolia* (476.33 g/m^2) and *Z. matrella* (630.33 g/m^2), this character is implied to higher growth rate and density of Tifdwarf along with genetic makeup and environmental adaptability. While, zoysiagrass has slowest growth among all and therefore isn't able to produce higher biomass even with highest density (Turgeon 2008).

Shoot density is a measure of number of aerial shoots per unit area (Turgeon 2008). It can vary with genotypic, natural environmental and cultural factors (Bell 2011). High density (dense) is the requirement for density, as the fundamental function of grass is to cover the soil (Janakiram and Namita 2014). In sports field, high density is required not only for covering the soil but also to form a cushion to reduce injury to players as well as to provide a smooth platform for sports activities. The data depicted in Table 2 clearly indicated that the most dense turf among the tested genotypes was *Z. tenuifolia* (227.14/25 cm^2) followed by *Z. matrella* (211.23 /25 cm^2) and 'Tifdwarf' (175.25 /25 cm^2) while lowest density was exhibited by *S. secundatum* (8.30/25 cm^2) owing to their other bio-agronomic characters like stolon internodal length, diameter and leaf length. Moreover, from the Table 8, it can be revealed that the lowest average stolon internodal diameter (0.35 mm) was observed in *Z. tenuifolia* followed by *Z. matrella* (0.42 mm). Within a turfgrass species, cultivars can differ widely in density (Turgeon 2008) as observed from the current study

Table 4 Vertical leaf growth rate (VLGR) of various turfgrass genotypes during different sampling months

Genotype	Year										Av. VLGR (mm/ day)
	2014									2015	
	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	
Cynodon dactylon var. Black Jack	0.37	0.22	0.17	0.66	0.66	0.65	0.25	0.16	0.21	0.19	0.35
C. dactylon var. Bargusto	0.16	0.11	0.21	0.27	0.28	0.27	0.19	0.11	0.12	0.09	0.11
C. dactylon var. Panama	0.18	0.27	0.14	0.32	0.32	0.32	0.19	0.08	0.10	0.08	0.20
C. dactylon var. Palma	0.25	0.23	0.18	0.30	0.33	0.32	0.27	0.12	0.13	0.11	0.22
C. dactylon var. Panam	0.11	0.19	0.18	0.62	0.70	0.69	0.28	0.12	0.11	0.11	0.31
C. dactylon var. Selection 1	0.08	0.07	0.01	0.14	0.15	0.19	0.09	0.03	0.03	0.02	0.08
C. dactylon var. Local	0.02	0.07	0.03	0.16	0.14	0.14	0.06	0.07	0.07	0.03	0.08
C. dactylon var. Tifdwarf	0.20	0.17	0.09	0.13	0.16	0.16	0.13	0.05	0.04	0.02	0.11
Axonopus compressus	0.02	0.09	0.05	0.27	0.33	0.30	0.10	0.11	0.11	0.05	0.14
Zoysia tenuifolia	0.01	0.02	0.05	0.09	0.10	0.10	0.05	0.01	0.01	0.01	0.05
Zoysia matrella	0.02	0.04	0.06	0.11	0.12	0.12	0.06	0.02	0.03	0.03	0.06
Stenotaphrum secundatum	0.23	0.10	0.08	0.11	0.11	0.10	0.07	0.27	0.05	0.03	0.11
Eremochola ophiuroides	0.10	0.14	0.11	0.37	0.39	0.39	0.18	0.11	0.12	0.12	0.20
CD (P= 0.05)	0.04	0.04	0.04	0.08	0.05	0.06	0.05	0.03	0.03	0.02	
CV (%)	17.26	19.79	22.27	16.95	11.16	12.49	20.24	17.70	21.89	20.80	

Table 5 Fresh clipping yield (g/m^2) of various turfgrass genotypes as affected by different sampling months

Treatment	Year										Cumm. fresh clipping yield (g/m^2)
	2014									2015	
	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	
Cynodon dactylon var. Black Jack	281.00	200.33	121.54	294.33	293.00	178.33	124.00	131.00	85.00	81.00	1789.53
C. dactylon var. Bargusto	233.00	273.00	224.33	234.67	233.00	211.67	151.33	151.33	168.00	134.33	2014.66
C. dactylon var. Panama	363.67	202.33	178.00	378.00	329.00	270.33	52.33	59.00	133.67	117.00	2083.33
C. dactylon var. Palma	351.33	290.67	213.00	423.00	296.67	132.00	123.67	127.00	104.67	100.00	2162.01
C. dactylon var. Panam	351.00	306.67	195.00	451.00	314.67	202.67	163.33	169.33	67.33	60.00	2281.00
C. dactylon var. Selection 1	146.00	225.67	118.00	193.00	265.00	260.33	189.33	189.00	126.00	94.67	1807.00
C. dactylon var. Local	406.67	224.67	190.67	435.00	290.67	255.67	101.33	104.67	129.33	123.00	2261.68
C. d. × *C. t.* var. Tifdwarf	494.33	392.33	268.31	466.33	379.67	386.67	375.00	374.67	175.67	180.00	3492.98
Axonopus compressus	175.33	188.00	154.00	180.00	224.33	329.67	155.33	163.67	119.00	80.00	1769.33
Zoysia tenuifolia	25.00	26.67	50.67	17.00	50.00	54.33	111.33	108.00	15.00	18.33	476.33
Zoysia matrella	31.00	31.67	52.00	18.33	52.67	100.67	142.33	147.33	33.33	21.00	630.33
Stenotaphrum secundatum	378.67	317.00	176.67	397.33	118.33	76.67	99.33	96.00	84.67	72.00	1816.67
Eremochola ophiuroides	365.00	349.00	182.33	424.67	131.00	306.00	120.33	119.33	162.33	169.67	2329.66
CD (P = 0.05)	40.18	54.74	36.62	46.79	47.02	38.30	32.52	33.49	20.07	24.25	
CV (%)	8.61	13.95	13.30	9.23	12.18	10.69	13.14	13.32	11.03	14.95	

Table 6 Leaf length (cm) of various turfgrass genotypes during different sampling months

Genotype	Year										Av. leaf length (cm)
	2014									2015	
	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	
C.dactylon var. Black Jack	6.62	2.21	4.54	6.86	7.12	6.78	4.65	4.47	6.17	6.10	5.55
C. dactylon var. Bargusto	4.18	1.39	4.58	4.54	5.04	5.01	4.79	4.61	5.58	5.51	4.52
C. dactylon var. Panama	5.83	1.94	5.22	6.74	6.30	5.97	4.53	4.40	4.55	4.30	4.90
C. dactylon var. Palma	4.28	1.43	4.56	6.70	5.29	4.96	5.10	5.06	5.05	5.11	4.70
C. dactylon var. Panam	6.36	2.12	4.85	6.96	6.86	7.19	4.55	4.76	4.92	4.76	5.33
C. dactylon var. Selection 1	3.59	1.20	2.31	2.13	2.35	2.23	3.12	2.92	1.72	1.80	2.33
C. dactylon var. Local	2.49	0.83	2.86	2.17	2.44	1.81	2.08	2.08	4.14	3.89	2.47
C. d. × *C. t.* var. Tifdwarf	2.44	0.81	2.03	2.24	2.39	2.24	2.59	2.40	2.59	2.58	2.23
Axonopus compressus	2.46	0.82	3.40	5.20	5.12	4.79	7.70	7.36	6.57	6.61	5.00
Zoysia *tenuifolia*	1.55	0.52	3.10	2.41	2.45	2.35	2.89	2.97	2.04	2.17	2.24
Zoysia matrella	1.56	0.52	4.09	2.79	2.65	2.51	3.26	3.29	2.16	2.19	2.46
Stenotaphrum secundatum	3.65	1.22	3.21	4.39	4.98	5.31	6.49	6.36	5.74	5.86	4.72
Eremochola ophiuroides	3.52	1.17	4.40	8.25	8.27	7.94	10.39	10.93	6.23	6.21	6.73
CD (P = 0.05)	0.91	0.67	0.93	1.01	1.19	0.81	1.00	0.95	0.88	0.83	
CV (%)	14.42	9.39	14.54	12.67	14.97	10.60	12.37	11.87	11.77	11.26	

and within *Cynodon* genus also the density has very wide range. Jankiram and Namita (2014) noticed that *C. dactylon* Palma showed very high density in contrast with the current study where Palma showed second lowest density among the tested *Cynodon* cultivars, this difference might be attributed to the difference in agro-climatic condition along with soil and management practices. Similarly, smaller leaf length is a desired character as it contributes to finer texture and better visual attribute (Table 6) and minimum leaf length was found in Tifdwarf and Selection 1, i.e. 2.23 cm. These

Table 7 Stolon internodal length (cm) of various turfgrass genotypes during different sampling months.

Genotype	Year										Av. stolon internodal length (cm)
	2014									2015	
	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	
Cynodon dactylon var. Black Jack	3.80	3.98	3.24	3.45	4.07	3.53	2.11	2.25	1.96	1.91	3.03
C. dactylon var. Bargusto	2.66	3.70	2.17	2.52	2.73	2.86	1.99	1.92	1.86	1.85	2.42
C. dactylon var. Panama	3.43	3.51	3.02	2.16	2.89	3.18	2.30	1.94	1.95	1.92	2.63
C. dactylon var. Palma	4.46	3.26	2.83	2.34	2.72	2.40	2.32	1.97	1.84	2.17	2.63
C. dactylon var. Panam	3.11	3.54	3.30	2.59	3.29	3.28	2.78	2.47	2.47	2.50	2.93
C. dactylon var. Selection 1	2.39	2.25	2.31	1.10	1.55	1.27	1.79	0.94	0.98	1.13	1.57
C. dactylon var. Local	1.92	2.22	1.22	1.02	1.52	1.26	1.60	2.09	1.91	1.80	1.65
C. d. × *C. t.* var. Tifdwarf	1.19	1.00	1.19	1.06	1.12	1.26	0.56	0.99	0.83	0.74	0.99
Axonopus compressus	2.48	2.73	2.32	3.13	3.08	3.22	2.64	2.20	2.12	2.09	2.60
Zoysia tenuifolia	1.03	1.04	0.81	0.76	1.33	1.30	1.33	1.34	1.49	1.41	1.18
Zoysia matrella	1.07	1.11	1.01	1.52	1.69	2.17	1.55	1.54	1.51	1.46	1.46
Stenotaphrum secundatum	4.52	4.59	3.39	2.51	3.05	2.73	2.14	3.43	3.49	3.52	3.33
Eremochola ophiuroides	2.02	1.76	1.99	1.25	1.30	1.70	1.38	1.40	1.35	1.56	1.57
CD (P = 0.05)	0.69	0.50	0.48	0.52	0.60	0.55	0.47	0.36	0.29	0.18	
CV. (%)	15.65	11.12	12.74	15.70	15.33	14.07	14.68	11.23	9.46	5.82	

Table 8 Stolon internodal diameter (mm) of various turfgrass genotypes during different sampling months.

Genotype	Year										Av. stolon internodal diameter (mm)
	2014									2015	
	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	
Cynodon dactylon var. Black Jack	0.92	1.00	0.97	0.81	1.01	0.82	0.72	0.76	0.80	0.76	0.86
C. dactylon var. Bargusto	0.82	1.02	1.27	0.91	0.82	0.91	0.64	0.66	0.69	0.65	0.84
C. dactylon var. Panama	0.87	1.15	1.17	0.92	0.87	0.95	0.69	0.70	0.73	0.76	0.88
C. dactylon var. Palma	0.88	1.03	1.18	0.88	0.88	0.89	0.62	0.63	0.71	0.77	0.85
C. dactylon var. Panam	0.82	0.99	0.95	0.69	0.82	0.68	0.61	0.63	0.73	0.71	0.76
C. dactylon var. Selection 1	0.53	0.58	0.81	0.69	0.53	0.61	0.63	0.64	0.59	0.59	0.62
C. dactylon var. Local	0.57	0.69	0.65	0.49	0.60	0.50	0.54	0.61	0.72	0.79	0.61
C. d. × *C. t.* var. Tifdwarf	0.59	0.59	0.57	0.41	0.59	0.44	0.45	0.47	0.48	0.45	0.50
Axonopus compressus	1.17	1.32	1.47	1.41	1.62	1.42	1.55	1.69	1.61	1.71	1.50
Zoysia tenuifolia	0.41	0.42	0.50	0.33	0.41	0.33	0.38	0.39	0.35	0.34	0.35
Zoysia matrella	0.41	0.44	0.57	0.38	0.41	0.38	0.42	0.43	0.38	0.38	0.42
Stenotaphrum secundatum	1.59	2.91	2.60	2.17	2.07	2.19	2.80	2.83	3.02	3.35	2.54
Eremochola ophiuroides	1.31	1.28	1.25	0.95	1.31	1.47	1.41	1.43	1.55	1.52	1.34
CD (P = 0.05)	0.20	0.13	0.15	0.19	0.25	0.25	0.17	0.14	0.11	0.27	
CV (%)	13.95	7.29	8.02	13.26	16.30	16.94	11.76	9.43	6.72	16.18	

results are in close accordance with study of Malik *et al.* (2014) and Ubendra *et al.* (2015).

The quality of a turf is a function of its utility, appearance and favourable characteristic according to its intended use (Turgeon 2008). Quality of turf is related to function and subjective requirement (Weicko 2006). Turf quality is a synthetic index evaluated by visual observations and it highlights the quality of turf. The most common way of assessing turfgrass quality is a visual rating system that is based on the turfgrass evaluator's judgement. During the entire period of experimentation, genotype that showed the highest mean values of quality rating was shown by Tifdwarf (8.30) followed by *Z. matrella* (7.98) and Selection 1 (7.76). Tifdwarf and *Z. matrella* also showed a good preservation of quality from April-2014 to Janaury-2015 (Table 9). During winter months (November-2014 to January-2015) most of the genotypes showed a decreasing trend in quality which is attributed to the low temperature associated with the loss of colour pigments as evident from the data relating to chlorophyll content. These values were extremely low due to the genotypic characteristics of above mentioned genotypes. The lower values of these genotypes have strongly influenced the mean of turf quality during whole period and also for single months. Turgeon (2008) reported that during the growth period, quality traits of turfgrass varied within every month which was supported by studies by Malik *et al.* (2014). Similar results for turf quality among the commercial cultivars and local ecotypes of bermudagrass were reported by Viggiani *et al.* (2015).

Maintaining dark green leaves is a key aspect of turfgrass management. Chlorophyll content represents the intensity of the green colour and is a quantitative quality indicator (Turgeon 2008). Chlorophyll content was estimated and present in Table 2. Chlorophyll contents have been positively correlated with visual turf ratings. Concentration of total chlorophyll among all species increased markedly in monsoon. Highest total chlorophyll content in all the seasons was exhibited by Tifdwarf 2.79, 3.30 2.65 and 2.59 mg/g at the end of summer, monsoon, post-monsoon and winter season, respectively. However, lowest chlorophyll content in all the seasons was shown by *S. secundatum*. The small increase in monsoon was associated with conditions more favourable for plant growth as a result of the precipitation received during monsoon season as described by Bell (2011). A decline in chlorophyll contents in all varieties was noted in December to February which in turn reduced the photosynthetic activity of the turfgrass. Chlorophyll content is influenced by genetic characteristics of the species, conditions of environmental stress (Viggiani *et al.* 2015 and Leto *et al.* 2008) as cultivar Tifdwarf showed maximum chlorophyll content (2.67 mg/g fresh weight) throughout experiment (Malik *et al.* 2014). In contrast, high light intensities aided by low temperature trigger the chlorophyll reduction, in the young leaf tissues that are more exposed to light, resulting in discoloration of foliage of few varieties.

Shorter stolon internodal length is required as they produce denser turf thus better visual quality. Tifdwarf (0.99 cm) showed shortest average internodal length (Table 7) followed by *Z. tenuifolia* (1.18 cm), *Z. matrella* (1.46 cm), Selection 1 (1.57 cm) and Local (1.65 cm). However, longest stolon internodal length was recorded in *S. secundatum* (3.33 cm). The differences among genotypes regarding stolon internodal length and diameter may be attributed to genetic constitution of individuals. Lower is the stolon internodal diameter better is the turf quality. It is explicit from the data (Table 8) that minimum average stolon internodal diameter (0.35 mm) was found in *Z. tenuifolia* followed by *Z. matrella* (0.42 mm) and Tifdwarf (0.50 mm), while *S. secundatum* registered maximum stolon internodal diameter (2.54 mm). The significant difference among genotypes

Table 9 Turfgrass quality rating (1-9) of various turfgrass genotypes during different sampling months.

Genotypes	Year										Average. turfgrass quality
	2014									2015	
	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	
Cynodon dactylon var. Black Jack	6.93	6.93	6.33	6.93	5.93	5.73	6.17	5.93	6.00	5.93	6.28
C. dactylon var. Bargusto	7.27	7.67	7.13	7.20	6.07	4.73	7.43	6.40	6.37	6.13	6.64
C. dactylon var. Panama	7.67	7.13	6.93	7.33	6.80	4.80	7.33	5.93	5.33	5.33	6.46
C. dactylon var. Palma	7.33	7.33	7.20	7.40	6.47	4.47	5.70	6.13	5.87	5.20	6.31
C. dactylon var. Panam	7.00	7.20	6.47	7.47	6.47	5.80	6.87	6.20	6.07	5.93	6.55
C. dactylon var. Selection 1	8.00	8.27	8.20	8.00	6.93	8.00	7.83	7.33	7.33	7.67	7.76
C. dactylon var. Local	8.33	7.90	8.80	8.33	6.93	5.47	7.43	7.40	7.47	7.40	7.55
C. d. × *C. t.* var. Tifdwarf	8.73	8.53	9.00	8.93	8.00	8.00	8.47	8.20	7.53	7.63	8.30
Axonopus compressus	5.67	6.60	7.47	7.40	6.53	6.53	7.13	5.27	5.20	4.87	6.27
Zoysia tenuifolia	5.60	7.40	8.60	8.33	7.93	8.33	6.23	8.33	7.30	7.20	7.53
Zoysia matrella	7.73	8.07	8.67	8.87	8.07	8.60	6.77	8.33	7.40	7.33	7.98
Stenotaphrum secundatum	6.27	7.13	4.93	7.20	7.13	7.60	7.67	5.93	5.93	4.93	6.47
Eremochola ophiuroides	7.53	7.87	8.13	7.80	7.27	7.93	7.27	6.80	6.80	7.47	7.49
CD (P = 0.05)	1.17	0.77	1.22	0.55	1.33	0.97	0.96	1.18	0.99	0.84	
CV (%)	9.55	6.09	9.62	4.17	11.34	8.74	8.06	10.34	9.02	7.79	

for stolon diameter is attributed to its genetic character. According to a similar study, most of the growth parameters including internodal length and internodal diameter varied significantly in all turfgrass cultivars during all months and in December, all cultivars showed reduction in all growth parameters as compared to the previous month (Malik *et al.* 2014) in Faisalabad, Pakistan. Findings of Rimi (2012) also indicated seasonality in internode development (length and width) with renewed growth during the active growing season, a neat drop in autumn (November onwards). Leto *et al.* (2008) also found significant differences among with tested genotypes with respect to stolon internodal length and diameter and termed it as a genetic character which differed significantly even within same species.

Leaf width is a parameter to measure of turfgrass texture (Turgeon 2008). It is a genetically controlled parameter mostly but in a stress condition, the leaf dimension may show adaptation. Narrow leaves allow for fine-texture turfgrass. For uniformity and smoothness, the requirements are for shoots of the grass to have the same shape, size and orientation (Christians 2004). The latter are not only for aesthetic reasons but also to increase rigidity and resiliency of the grass to endure compaction or to support golf balls (Turgeon 2008). The results in Table 2 showed that the leaf width was smallest in *Z. tenuifolia* (1.05 mm), followed by Tifdwarf (1.17 mm), *Z. matrella* (1.26 mm), while widest leaf was found in *A. compressus* (8.38 mm). Similar findings regarding leaf width were reported by Harivandi *et al.* (1984) and Turgeon (2008).

Plants absorb water primarily through their root systems and turfgrass species differ in their rooting abilities (Harivandi 1984). Some species have deep root systems, other shallow ones. Warm season turfgrasses generally produce deep root systems (Turgeon 2008). Grassland with deeper and denser rooting can take up more nutrients and water, which increases productivity and reduces nutrient losses. The choice of specific grass species and cultivars could be an effective management tool to enhance rooting depth and density. Findings from result (Table 2) suggest that Local had deepest roots (24.50 cm), while, Tifdwarf (9.67 cm) displayed shallowest root depth. These findings are in line to those of Harivandi (1984) who found that St. Augustine, zoysiagrass and bermudagrass possess deep root system but this may vary with variety, management practices and response to weather variables by the cultivar. Genetic variation is the main reason among different grass species or cultivars for wide differences in root depth (Janakiram and Namita 2014). Root mass and density in grassland can be influenced by the choice of grass species and cultivars although, the rooting depth of each turfgrass species is genetically controlled and environmental factors also affect it considerably (Weicko 2006). Roots can penetrate deeper in sandy than in clay soils; deeper in fall and spring than in summer, winter and are deeper when the grass is mowed higher (Beard 1973). Other environmental factors affecting turfgrass root depth are irrigation, fertilization, soil compaction and shade (Turgeon 2008).

Prostrate growth habit is desired for turfgrass, as prostrate grass can be maintained at lower mowing height and in addition, the grass can spread faster as the mature shoots are in contact with the ground and thus, the nodes could easily root (Gobilik *et al.* 2013). Tifdwarf, Local, *A. compressus, S. secundatum* and *E. ophiuroides* displayed prostrate growth habit, whereas other genotypes, viz. Panama, Selection 1, *Z. tenuifolia* and *Z. matrella* showed semi-prostrate growth habit (Table 2) while, others showed upright growth habit which is an undesirable trait.

From the present investigation, it can be concluded that under south Gujarat agro-climatic condition, *C. dactylon* × *C. transvaalensis* Tifdwarf performed best in all turf quality parameters and can be subjected to further functional quality trials for sports and athletics turf. For the requirement of low maintainence home lawns and public places, *Z. matrella* can be used as it maintained good turf quality. *Z. tenuifolia* also performed good considering many agronomic parameters but lagged behind in turf quality rating. Among coarse textured grasses, *E. ophiuroides* registered good quality rating and can be used along road sides for beautification and soil stabilization as it showed better turf intensity rating. Tifdwarf displayed best aesthetic quality in the whole period of experimentation which was closely followed by *Z. matrella*. Tifdwarf can be recommended for the use on fairways, tea and golf greens of golf course. It is also very good for other sports fields.

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