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Evaluation of quality, growth, and physiological potential of various turf grass cultivars for shade garden

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Abstract Achieving excellent performance of the warm season turfgrasses under low light environment is a bit difficult task. The present study was designed to explore the response for quality, growth, and physiological potential of various turfgrass cultivars adopted in today's landscape. During the growth period of six months, all cultivars exhibited variations in color, texture, and visual quality. Maximum quality scores (8.2) for color were achieved in cultivar 'Fine Dacca'. Stolon diameter was maximum (2.1 mm) in the ecotype Khabbal in the month of December. Maximum fresh weight of clips (4.2 g) was noted in the cultivar Fine Dacca in the month of April followed by the ecotype Khabbal. Similarly the rate of photosynthesis was higher in the cultivar Fine Dacca (7.23 µmole $m^{-1}S^{-1}$) in the month of March followed by Tifway. Higher Chlorophyll contents (2.73 mg g^{-1} FW) were observed maximum in the cultivar Tifway in the month of December. Similarly, all cultivars exhibited contrasting results for transpiration, stomatal conductance and internal carbon dioxide concentration under the sun and shade conditions. From the results of the present study it was found that Bermudagrass cultivar 'Fine Dacca' performed better under sunny conditions, whereas, Zoysiagrass cultivar 'Korean' performed better under shady conditions.

Key words

Bermuda grass, Gardening, Lawn, Physiology, Tolerance

Growing turfgrasses 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 (19). Additional benefits related to turfgrass are to protect houses and recreational places from dust and mud and safeguard against the intensity of glare and heat. It is commonly observed that 20-25 percent of the total turfgrass grown found under some extend of shade (1). The microclimate of the shaded turfgrass is different from the sunny conditions as it received less light intensity, mediocre light quality, moderate temperature, with high relative humidity (32). Most turfgrass varieties are affected adversely as they received less than 4-5 hrs of direct sunlight daily as evergreen plants can block 95 percent of the available sunlight. Reduction in wear and stress tolerance because of shade leads to higher disease prevalence and more algae invasion. All turfgrass species exhibited inferior turf quality under high shade as indicated by an increase in weak, succulent vertical growth with less-dense turf sward (27). Consequently, turfgrass management applies under shady conditions are different from that of full sun (7). Shade is a major limiting factor in landscape for turfgrass. To establish turfgrass under shade is difficult as low light changes turfgrass growth and responses to management techniques. In shade, turfgrass cells and leaves become thin and elongated. As the amount of carbohydrates is reduced under shade, turfgrasses have fewer tillers and smaller root systems. Thus, turfgrass density is diminished over time by attrition resulting in a gradual deterioration of the turfgrass stand (28). Mechanisms of shade acclimation of turfgrass species are not well known in particular for those differing in low light tolerance. Shade either from trees or buildings present a problem in the management of turfgrasses. Under dense shade conditions, the quality of light is also a critical factor for optimum turfgrass growth. Turfgrass grown under shade conditions is specially subjected to increase disease occurance and traffic stress due to the subtle nature of the turfgrass (5,18). Only a few turfgrasses can survive long term when shading exceeds 75%. In addition, turfgrass plants have to experience fluctuating irradiance because of shading effect of tree canopy and buildings and also due to different weather pattern. Shaded plants whenever exposed to high light are relatively more susceptible to photo-inhibition compared with plants grown in full sunlight. Shade cause reduction in growth of warm season species such as bermudagrass (*Cynodon dactylon*). The adverse effect of shade on bermudagrass includes; reduction in root and rhizome growth, decrease tiller formation, slow lateral growth, increase internodal distance and disrupt the green color of leaves.

An efficient method to grow turfgrass in shade is to identify shade tolerant varieties having more adaptability to survive under shade conditions. Different turfgrass species have variable morphological, physiological, and anatomical responses to shade such as St. Augustinegrass growth vigorously under shade whereas, bermudagrass exhibits poor growth. Other warm season species like *Zoysia spp., Axonopus affinis, Paspalum notatum* and *Eremochloa ophiuroides* showed variable growth under shade.

Management of turfgrass under shade conditions is a challenging task for golf course managers and gardeners. Also with the recent trend to use turfgrass for indoor sports facilities have accelerated to develop strategies for turfgrass management under reduced irradiance. Thus the present study was initiated to investigate the comparative performance of warm season turfgrasses i.e. bermudagrasses (‘Tifway’, ‘Tifdwarf’, ‘Fine Dacca’, and one ecotype) and one cultivar of zoysiagrass (‘Korean’) under sun and shade conditions. The objectives of the present study were to assess the effect of shade on locally available various bermudagrass and zoysiagrass cultivars and to categorize turfgrasses on the basis of morphological and physiological characters which make these turfgrasses shade tolerant.

Materials and Methods

Germplasm source and layout plan

The present study was carried out on three Bermudagrass cultivars including ‘Tifway’, ‘Tifdwarf’, ‘Fine Dacca’, one cultivar of zoysiagrass popular as ‘Korean’, and one ecotype of Bermudagrasses (‘Khabbal’). Turfgrass were established in different plots under sun and shade conditions. Equal size (4 cm^2) plugs were planted in plots measuring 25.66 m^2 (7.01 m X 3.66 m) during the 2^{nd} week of September on well prepared and leveled soil surface. The experiment was laid out according to Randomized Complete Block Design (RCBD) in split plot arrangement with five treatments replicated thrice to neutralize the effect of the soil fertility. Green nets were used to provide the shade which blocked 70% of the light rays. The shade stand was arranged 90 cm above the turfgrass surface by bamboo sticks. The other plots were established under sunny and exposed conditions.

Quality and growth parameters

Various turfgrass quality parameters were recorded as turfgrass quality was judged using a visual rating scale. The color of turfgrass was rated as: 1=brown turf, 5=medium green turf, and 9=dark green turf. Turfgrass texture was determined by using following rating: 1=coarse, wide blades, 5=medium blades, and 9=very fine blades. The texture was evaluated visually by investigative the leaf blades of cultivars under study. Turfgrass density was estimated by using following scores: 1=little to no turf, 5=50% turf, and 9=complete stands of turfgrass. Similarly, to estimate the uniformity the grading was: 1= presence of bare areas, weeds, and damaged and diseased turf, 5=minimum bare areas, weeds, less damaged and diseased turf, 9=absence of bare areas and weeds, etc. Overall turf quality was visually determined after considering the ratings for color, density, texture, and uniformity. Overall turf quality was ranked: 1=poor, 5=average, and 9=excellent.

Data collection

Data regarding growth parameters such as internodal length (cm), leaf length (cm), leaf width (mm), and stolon width (mm) were measured. In total, 15 samples were collected for each cultivar either under the shade or sun for each growth attributes. Moreover, for fresh and dry weight of turfgrass clippings, samples were collected after 15 days of mowing with the help of the rings covering the area of 0.076 m^2 thrown randomly in each plot. Shoot fresh weight was measured in grams on an electric balance. Data about physiological parameters was taken as photosynthetic rate or net CO_2 assimilation rate (Pn), transpiration rate (E), stomatal conductance (g_s), and sub-stomatal CO_2 concentration/Internal CO_2 conc. (C_i) on a fully expanded leaves of all with the help of open system LCA-4 ADC portable infrared gas analyzer (Analytical Development Company, Hoddesdon, England). At the end of every month, chlorophyll contents of all cultivars were estimated using following formula.

A = [(0.0127 (OD 663)-0.00269 (OD645) *100] /0.5 = mg/g of fresh weight

B = [(0.0229 (OD 645)-0.00468 (OD663)*100] /0.5 = mg/g of fresh weight

Statistical analysis

Data regarding all the parameters of the experiment were analyzed statistically using the method described by Steel et al. (25). Analysis of variance (ANOVA) was performed to check the significance of the results for all parameters. Each cultivar’s performance was compared using Duncan’s Multiple Range Test at 5% probability level (10).

Results and Discussions

Qualitative traits

The performance of all cultivars varied significantly under sun and shade for most of the quality and growth parameters as depicted by analysis of variance and their relative performance was evaluated by DMR test. However, for some parameters non-significant results were also achieved as mentioned in the Tab. 1. During six month growth period, quality traits of turfgrass varied with in every month. Under sunny conditions color of the varieties ranged from light to dark green in hue in all months with the maximum (8.2) quality scores for the 'Fine Dacca' and minimum scores (6.40) for the local ecotype 'Khabbal' in November, and cv. 'Fine Dacca' with the minimum quality scores (3.6) in January, as presented in the Table. 1. In contrast, the performance of all cultivars in shady condition was reduced in quality of color of turfgrass during period of study. In these circumstances the Zoysiagrass cultivar 'Korean' performed better in November, scoring maximum quality points (7.26) among all other cultivars during all months having medium to dark green foliage color of turfgrass. Poor performance with respect to color quality was exhibited by the cultivar 'Fine Dacca' scoring 4.95 points in February. In the present study, non-significant results by all cultivars were exhibited for color quality in December, and February months. Fluctuations in the performance of the selected cultivars could be attributed to the temperature as very low and extremely high temperature regime adversely affects the growth of plants (17,24). These differences in the patterns of color quality in all cultivars during their growth period under sun and shade were explained by Beard (1) who concluded that the degradation in color are attributed to specific nutrient deficiency, drought stress, and may be due to disease occurance. Another possible reason for low color quality is that shade decreases the photosynthetic photon flux (PPF) therefore, changes the spectral composition, in particular red: far red (R:FR) ratio, while shade-cloth (or neutral-density) shade lowers photosynthetic photon flux (11) which in turn can influence and show a decrease on tiller formation and chlorophyll contents (30). The texture of the turfgrass varied from fine to course as in November, when all the cultivars showed medium to fine texture except ecotype 'Khabbal' securing 4.16 quality points under the sun. During the whole growth period all cultivars showed significant differences in texture. All cultivars showed poor results to obtain fine texture as the minimum (2.76) quality points were scored by the cultivar 'Fine Dacca' representing coarse texture in sunny conditions. Under shady conditions similar behavior was noted in November. Significant differences in texture quality were yielded by all cultivars during all months as mentioned in the Table. 1. Again 'Fine Dacca' scored less quality points as compared to others for all months. Better quality texture with fine surface was and less blade width was yielded by 'Tifdwarf' leading all other cultivars for the remaining months as well.

Density of selected turfgrass cultivars significantly varied only in December. 'Tifway' (6.63) and 'Tifdwarf' (6.60) behaved in a similar way, showing the maximum density of the turfgrass. Poor performance was exhibited by the ecotype 'Khabbal' producing minimum (5.70) density turfgrass. Performance of cultivars in the remaining showed non-significant results for all cultivars with respect to density. In shady environment, all cultivars varied in density in November, only. However, in the remaining month's performance of cultivars was the same, hence non-significant differences were observed (Table 1). Again the uniformity of the turfgrass varied significantly only in December whereas, 'Tifway' and 'Fine Dacca' showed the uniform spread of the turfgrass scoring 7.90 and 7.70 points, respectively. Moreover, 'Korean' and Ecotype 'Khabbal' showed similar behavior scoring 7.30 and 7.03 respectively. A non-significant difference was recorded in turfgrass uniformity in all other months. Under shady conditions, uniformity of turfgrass varied significantly in all genotypes as presented in the Table 1. Under sunny conditions, overall turfgrass quality varied significantly in the months of November, January and April. However, non-significant response in overall turfgrass quality was noticed in the remaining months during their growth in sunny conditions. Cultivars 'Tifway', 'Tifdwarf' and 'Fine Dacca' behaved similarly in January, February and March. In contrast, under the shade overall turfgrass quality varied significantly in all months except December. Performance of 'Korean' was remarkably better in theses months under the shade as compared to other selected cultivars as shown in the Table. 1. Similar studies were performed by Stypczynska and co-researchers (26) who assessed the rate of covering of sod. Results indicated that the highest parameters of assessed traits were found in one of the cultivars (Tarmena) *Festuca arundinacea*. The lowest values were found in cultivars of *F. ovina*, which at the same time, were characterized by the highest rate increase in root weight and length.

Growth parameters

Varying response of all cultivars for the growth parameter was depicted in Fig. 1 and 2. Most of the growth parameters including internode length, leaf length, fresh and dry weight of clippings varied significantly in all cultivars under both growing conditions during all months. In November, maximum internode length was presented by the ecotype in sunny (3.84 cm) and shady (3.91 cm) conditions. Stolon and leaf width did not vary significantly under sunny and shady conditions in all cultivars. Leaf length also showed highly significant results and maximum leaf length (6.1 cm) was observed in the ecotype 'Khabbal' under both growing conditions. Fresh and dry weight also showed variations in all cultivars under sunny and shady conditions, however, a similar trend of increment in fresh and dry weight in the form of columns was shown during both conditions. In December, all cultivars showed reduction in the quantity of all growth parameters as compared to the previous month. The overall trend of growth parameters by all cultivar is presented in the Fig. 1B. The above results are in accordance with findings of researchers (2, 3, 15) where shade limited the growth of warm season grasses: bermudagrass (*Cynodon dactylon*). The fluctuations in the morphological traits could be attributed to response of grass against low intensities of light (30) which in turn affected the nutritional status, hormonal level, and photosynthesis and anti-oxidation activity of the cells (31). Moreover, many researchers argued that the roots play an important role in forming the shoot weight (12, 33).

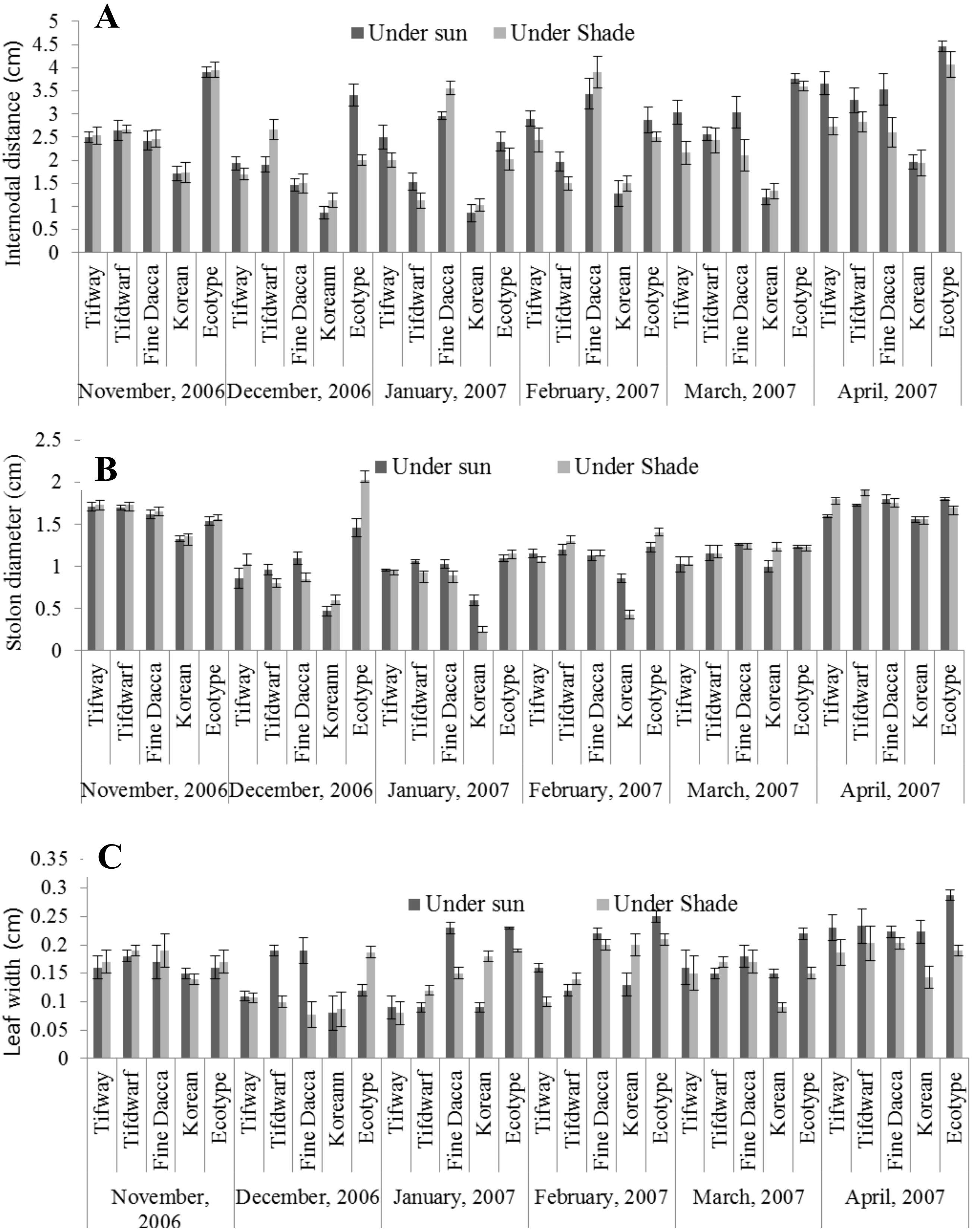

Fig. 1. Growth attributes of turfgrass under sun and shade. A, Intermodal distance; B, Stolon diameter; and C, Leaf width.

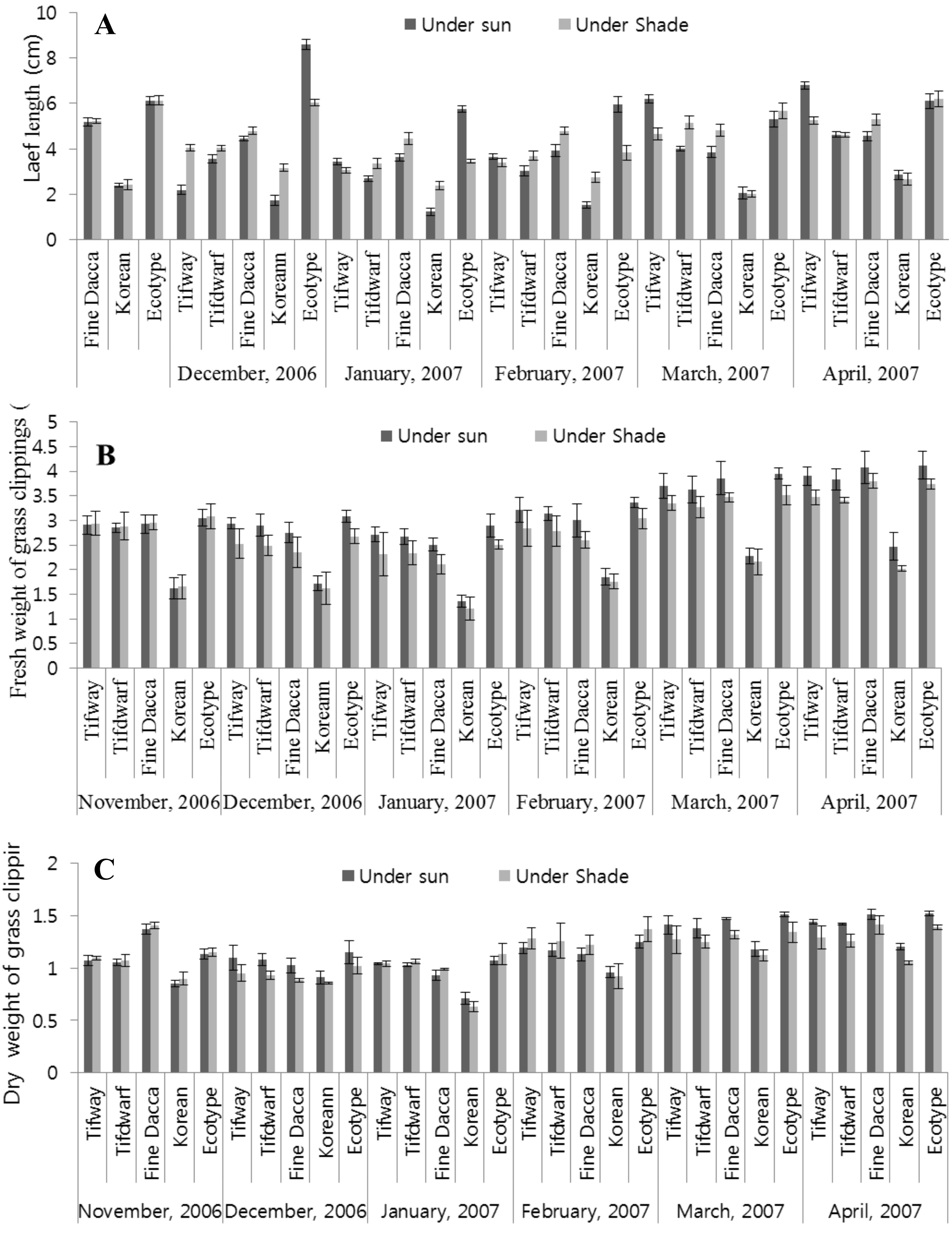

Fig. 2. Growth parameters of turfgrass under shade and sun. A, Leaf length; B, Fresh; and C, Dry weight of grass clippings.

Physiological attributes

Comparative performance of the cultivars for physiological attributes significantly varied during whole growth period. Physiological performance was depicted in the form of photosynthetic rate, which differed significantly (P<0.01) among all cultivars during all months. Comparison of photosynthetic activity under sunny and shady conditions showed significant variations. All cultivars showed more photosynthetic activity under the sun with the better performance of 'Korean' with the maximum photosynthetic activity (7.9 $\mu mole \cdot m^{-2} \cdot S^{-1}$). Under shady environment 'Tifdwarf' exhibited maximum (6.89 7.9 $\mu mole \cdot m^{-2} \cdot S^{-1}$) in March. 'Korean' again performed better in November for photosynthetic activity under shady environment. For the performance of the warm season turfgrass, low light intensities along with the combination of low temperature are the limiting factors which reduce the turfgrass quality, promotes browning and lowers the photosynthetic activity of the grasses (1) as the warm season turfgrasses are photosynthetically active at 27-35°C (20). Transpiration rate also showed fluctuations in both growing environments. Maximum transpiration rate (2.52 $mmole \cdot m^{-2} \cdot s^{-1}$) under the sun was exhibited by the cultivar 'Fine Dacca'. The most important finding is that 'Fine Daaca' also performed better under shady conditions in November when there was low temperature in the field. Cultivar 'Korean' also showed higher transpiration rates during the whole growing period in all months. Similarly, variations in the stomatal conductance were also observed in all cultivars during each month in both growing conditions as shown in Fig. 3C. It is obvious that excessive moisture in the root zone under shady environment increases the stomatal conductance and transpiration rate, which is favorable for the grasses to avoid water logging conditions, especially in low temperature in December and January when turfgrass growth is limited (4, 6, 22). In contrast, Dormaar and Sauerbeck (9) argued that grass plants continue to respire during winter though the respiration rate decrease with temperature and are minimal at -5°C and vary among various species of turfgrasses but excessive shading may reduce the cold tolerance in plants which in turn reduces the plant vigor (13, 16, 21).

Under shady and sunny conditions all cultivars varied for internal CO_2 concentrations and the chlorophyll contents in both environmental regimes. The main focus was to the performance under low light environment as maximum internal CO_2 concentration was observed in 'Tifway' (1.2 ppm) followed by 'Tifdwarf' (1.98 ppm) as presented in Fig. 4A. Similarly chlorophyll content (a/b) also differed in all cultivars in both growing environments with the best performance of 'Tifdwarf' for its maximum chlorophyll contents (2.67 $mg \cdot g^{-1}$ FW). Variations in the chlorophyll contents in sunny and shady environment could be attributed to the fluctuations in the total available light for turfgrass growth activity. It is clear that warm season turfgrasses perform poorly under low light conditions (20). A decline in chlorophyll contents in all varieties was noted in December to February which in turn reduced the photosynthetic activity of the turfgrass (14). 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 (8, 23).

It is obvious from the present findings that all the selected turfgrass cultivars showed better performance for some parameters, but for some attributes their performance was not satisfactory. Thus, based on an overall basis, the cultivar 'Fine Dacca' proved best suited to sunny conditions and the cultivar 'Korean' claimed better choice for shady places in the lawns. 'Korean' turfgrass cultivar exhibited slow growth rate, reported to be the best cultivar under shade due to its excellent turf quality (29). It can be concluded that to maintain good quality turf in shade, shade tolerant grass cultivar such as 'Korean' should be selected.

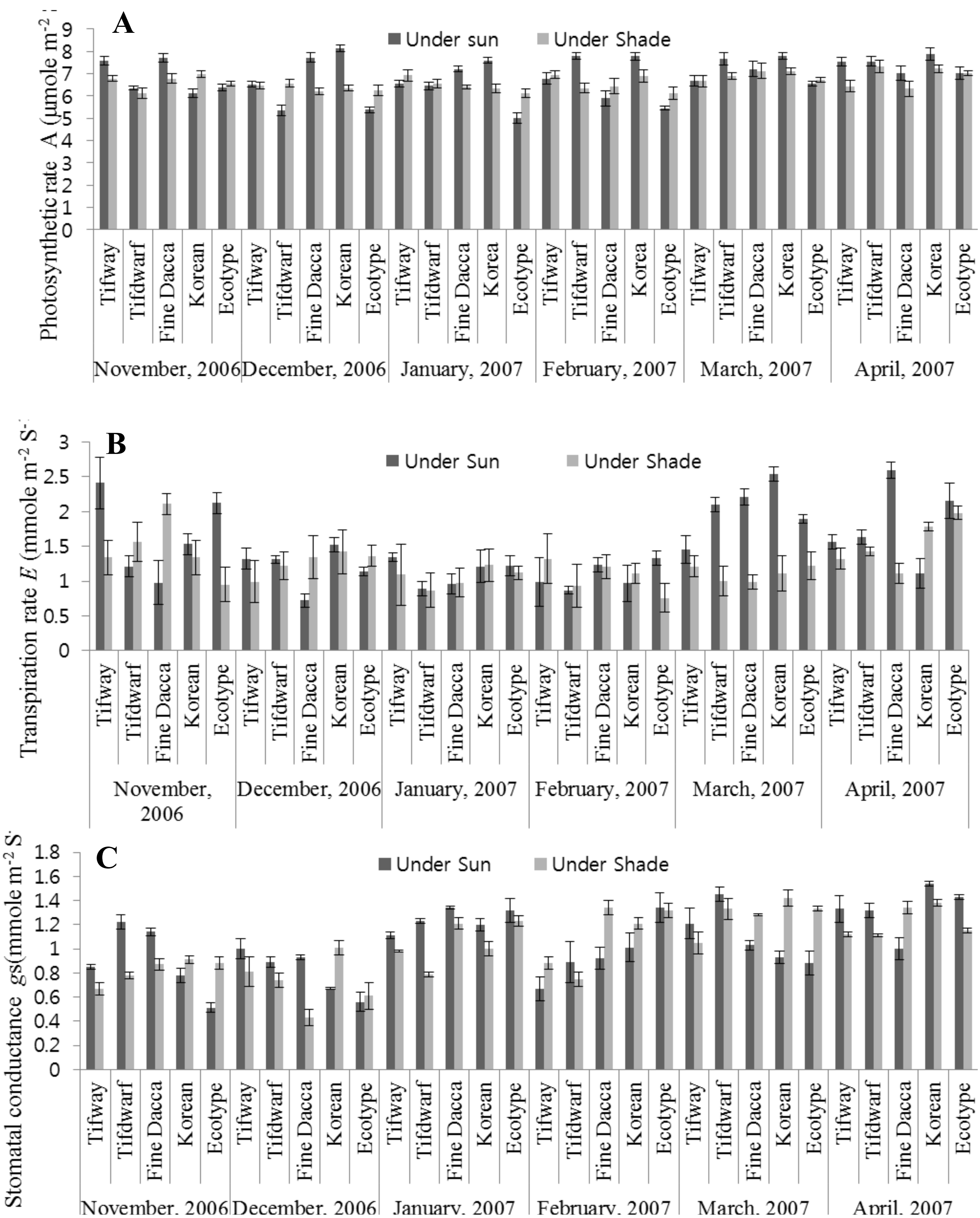

Fig. 3. Physiological attributes of turfgrass under shade and sun. A, Photosynthetic rate; B, Transpiration rate; and C, Stomatal conductance.

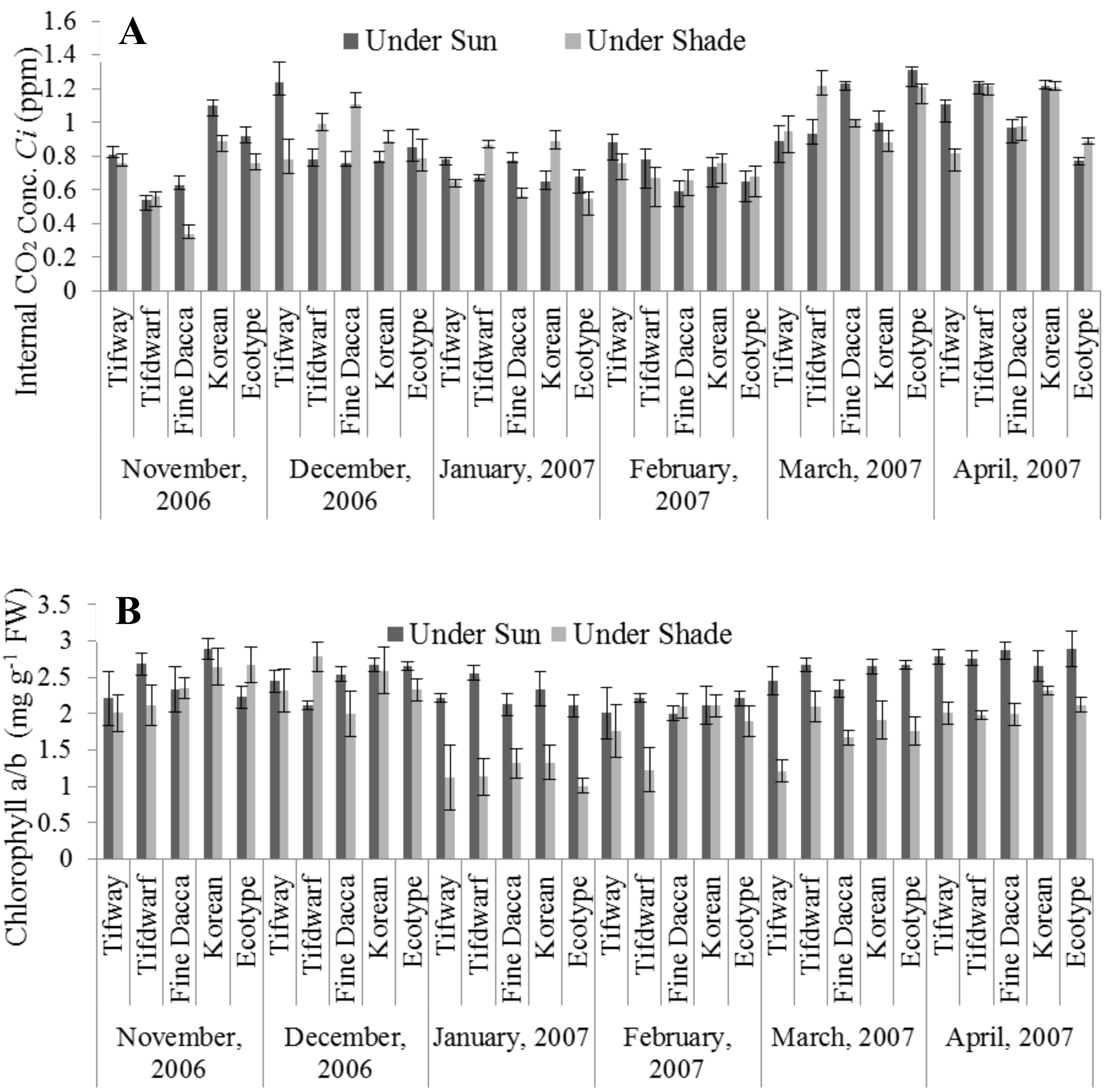

Fig. 4. Physiological attributes of turf grasses under sun and shade. A, Internal CO_2 concentration; B, Chlorophyll a/b contents.

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Table 1

Comparison of quality parameters under the sun and shade during 6 month growth period.

		Under sun					Under shade				
	Varieties	Color	Texture	Density	Uniformity	Turf quality	Color	Texture	Density	Uniformity	Turf Quality
November	Tifway	7.50 a	8.16 ab	7.233	5.7	6.08a	4.46 b	7.73 a	6.26 b	5.66 c	6.03 b
	Tifdwarf	6.76 b	8.23 a	7.267	6.467	6.943a	4.56 b	8.06 a	6.66 b	6.43 b	6.43 b
	Fine Dacca	8.20 a	7.30 b	7.867	7.4	7.593a	5.60 ab	6.63 b	7.96 a	7.63 a	6.96 a
	Korean	7.90 a	8.66 a	5.5	4.5	5.887ab	7.20 a	7.26 a	7.06 b	6.50 b	7.26 a
	Ecotype	6.40 b	4.16 c	6	5.133	5.537b	6.70 a	7.33 c	5.36 c	4.96 d	5.59 c
	LSD value	0.7292	0.8871	NS	NS	0.321	1.845	0.877	0.901	0.63	0.413
December	Tifway	6.06 abc	7.23 a	7.63 a	7.90 a	7.21 a	7.067	7.36 a	5.033	5.733	6.303
	Tifdwarf	4.73 c	7.26 a	7.60 a	7.03 ab	6.66 a	7.767	7.50 a	6	6	6.82
	Fine Dacca	7.73 a	5.50 b	6.66 ab	7.70 a	7.15 a	6.5	5.43 b	5.367	5.267	5.657
	Korean	7.16 ab	7.40 a	7.00 ab	6.30 b	6.97 a	7.767	7.73 a	6.7	6.733	7.233
	Ecotype	5.16 bc	4.53 c	5.70 b	6.03 b	5.36 b	7.333	7.03 ab	4.4	4.133	5.6
	LSD value	1.999	0.6329	1.555	1.17	0.423	NS	1.207	NS	NS	NS
January	Tifway	4.5	5.20 a	6.967	5.2	5.47	5.1	5.13 ab	6.3	5.96 ab	5.63 a
	Tifdwarf	3.66	4.76 a	7.367	7.4	5.803	5.5	4.00 b	7	6.96 a	5.87 a
	Fine Dacca	3.6	2.76 b	8.433	8	5.703	3.803	2.86 c	5.333	4.80 b	4.21 b
	Korean	6.3	5.73 a	6.7	6.633	6.343	5.3	6.20 a	6.267	6.30 a	6.02 a
	Ecotype	4.43	3.10 b	5.867	5.633	4.76	4.567	6.66 b	5.333	5.	5.06 ab

											70 ab	
	LSD value	NS	1.174	NS	NS	NS	NS	1.093	NS	1.217	1.101
February	Tifway	4.83 ab	5.40 a	6.667	5	5.47	5.4	5.36 ab	6.1	5.73 ab	5.653ab
	Tifdwarf	3.83 b	5.06 a	7	7.033	5.737	5.8	4.20 cd	6.76	6.80 a	5.893a
	Fine Dacca	3.76 b	2.96 b	8.067	7.667	5.613	4.3	3.13 d	5.13	4.56 b	4.953c
	Korean	6.43 a	5.73 a	6.433	6.333	6.237	5.733	6.40 a	6.03	6.13 a	6.077a
	Ecotype	4.63 b	3.26 b	5.667	5.433	4.75	4.767	6.90 bc	5.1	5.50 ab	5.07b
	LSD value	1.659	1.26	NS	NS	NS	NS	1.09	NS	1.269	1.451
March	Tifway	6.867	6.16 a	7.2	5.7	6.483	6.533	5.73 ab	6.533	6.10 ab	6.22 ab
	Tifdwarf	5.9	5.86 a	7.5	7.267	6.637	5.567	5.26 bc	7.267	7.23 a	6.32 ab
	Fine Dacca	5.867	4.13 b	8.467	8.033	6.627	5.6	3.83 d	5.6	5.06 b	5.08 c
	Korean	6.667	6.40 a	7	7	6.767	6.633	6.46 a	6.7	6.70 a	6.53 a
	Ecotype	6.133	4.36 b	6.4	6	5.73	6	6.63 cd	5.533	6.00 ab	5.58 bc
	LSD value	NS	1.024	NS	NS	NS	NS	0.8951	NS	1.341	0.7243
April	Tifway	7.36 ab	7.23 a	7.533	6.3	7.11a	4.46 c	6.53 a	6.8	6.3	6.02 bc
	Tifdwarf	6.90 b	6.63 a	7.833	7.6	7.243a	4.73 bc	5.86 b	7.467	7.433	6.37 ab
	Fine Dacca	7.90 a	5.36 b	8.467	8.2	7.473a	5.43 b	4.70 c	6.133	5.3	5.39 c
	Korean	7.90 a	7.36 a	7.567	7.367	5.553b	7.26 a	7.06 a	7.033	6.933	7.07 a
	Ecotype	6.86 b	5.33 b	6.967	6.367	6.383ab	6.96 a	5.46 b	6.033	6.3	6.18 b
	LSD value	0.6468	0.7944	NS	NS	0.831	0.7095	0.5585	NS	NS	0.436