



Effects of Bermudagrass Cultivar and Plant Growth Regulator Use on Turf Sustainability and Aesthetics

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The average 18-hole golf course is predominantly comprised of rough areas. If the mowing frequency of these turfgrass areas were reduced without compromising aesthetic value by using cultivars with inherently slow vertical growth combined with plant growth regulators, the labor hours, fuel and budget allocated to turf maintenance could be vastly decreased. The objective of this research was to determine if bermudagrass (*Cynodon* spp.) cultivar selection and trinexapac-ethyl (TE) use can significantly reduce the mowing events required to maintain bermudagrass at a one-inch height with mowing frequency based on the one-third rule without compromising turfgrass aesthetics. 'Discovery' bermudagrass treated with TE required the lowest number of August mowing events to maintain the turf at a one-inch height, followed by 'Discovery' without TE, as well as 'Celebration', 'TifGrand', and 'Tifway' treated with TE. 'Celebration', 'TifGrand' and 'Tifway' without TE, as well as 'Patriot' and DT-1 with or without TE required the greatest number of mowing events. Turf quality of 'Discovery', 'Celebration', and 'Patriot' bermudagrass was not affected by TE. 'TifGrand' treated with TE produced the lowest turf quality, while DT-1 without TE produced the highest turf quality. 'Discovery' bermudagrass produced the darkest green genetic color, followed by 'TifGrand' and 'Tifway', then 'Patriot' and 'Celebration', and finally DT-1. If turf managers began utilizing slow growing bermudagrass cultivars, coupled with TE use to decrease mowing frequency requirements, substantial reductions in labor hours, fuel consumption and greenhouse gas emissions would be observed.

The average 18-hole golf course covers 150 acres and is predominantly comprised of rough areas [(51 acres (Lyman et al. 2001)]. In the Southeastern United States, rough areas, as well as sports fields are typically bermudagrass (*Cynodon* spp.). Over the last 60 years, breeding efforts have developed several hybrid ($2n = 3x = 27$) bermudagrass varieties, as well as improved common ($2n = 4x = 36$) types with a wide variety of physiological traits. Favorable, selectively bred traits include characteristics such as decreased mowing height, increased density, improved quality and color, and cold tolerance (Burton, 1966). Other characteristics that differ by cultivar include shade tolerance (2, 19), salinity tolerance (13), divot resistance and recovery (Karcher, 2005), golf ball lie (Trapp et al. 2011a), irrigation requirements (Baldwin et al., 2006), nematode resistance (Pang et al., 2011), and traffic tolerance (Trappe et al., 2011b).

Regardless of these differences, when air temperatures exceed 80 °F, bermudagrass typically requires frequent mowing to maintain adequate turfgrass quality and good playing conditions (Trappe et al., 2011c). Because turfgrass requires frequent mowing, a large portion of the typical maintenance budget is devoted to mowing equipment, fuel and labor (Turgeon, 2008). Despite the vast variability in bermudagrass cultivar physiology, current research has not explored the effects of inherent vertical shoot growth rates on mowing frequency requirements. If bermudagrass

cultivars that required a reduced mowing frequency were utilized the labor, fossil fuel consumption and budget necessary to mow the turfgrass could be substantially reduced.

Plant growth regulator (PGR) use has become a popular facet of turfgrass management. Benefits of PGR use include increased shoot density and tillering, drought tolerance, increased nutrient retention and reduced vertical shoot growth (Fagerness and Yelverton, 2010). Effects of PGRs on bermudagrass include, but are not limited to, increased stolon mass, rhizom mass and chlorophyll concentration (McCullough et al., 2006), as well as reduced clipping yields (Fagerness and Yelverton, 2010). McCullough et al. (McCullough et al., 2006) observed a 67% reduction in clipping yield of 'TifEagle' bermudagrass when treated with trinexapac-ethyl (TE) and maintained at a 3.2 mm cut height. Fagerness and Yelverton, 2010 documented a 40% reduction in 'Tifway' bermudagrass seasonal tissue production following sequential TE applications, as well as shoot growth inhibition lasting up to four weeks. While the effects of TE on clipping yield reduction have been well documented, presently no research has explored the impact of TE on mowing frequency requirements.

If the mowing frequency of golf course roughs [51 acres (Lyman et al., 2001)] was reduced from twice to once a week using bermudagrass cultivars with inherently slow vertical growth combined with PGRs, without compromising aesthetic value, managers would be saving approximately \$124 per week, \$496 per month and \$2,976 over a six-month summer growing season on fuel and labor alone. The above calculations are based on the

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current price of diesel fuel, [\$3.89/gal (U.S. Energy Information Administration. 2013)], federal minimum wage (\$7.25/h (U.S. Department of Labor. 2013)], and the fuel efficiency specifications of a Toro Groundsmaster 4300-D [3 acres/gal and 6.4 acres/h, respectively (Toro, 2014)]. This translates to a savings of approximately \$7,726,337 and 1,059,256 gal of diesel to mow the 132,407 acres of bermudagrass rough area over a six-month summer growing season in the Southeastern United States (Lyman et al., 2001). Similar savings could be expected on commercial, residential, athletic and municipal turfgrass areas as well.

However, applying PGRs, such as TE, to decrease mowing frequency is a substantial financial sink. The cost of monthly TE applications to 51 acres of golf course rough is approximately \$1,785/month, which nearly negates the potential savings (\$496/month) provided by reducing the mowing frequency from twice to once a week. The estimated cost of TE applications to the golf course roughs include: the approximate cost of product, Primo Maxx (Syngenta, Greensboro, NC) (\$6.23/acre); current price of gasoline (\$3.61/gal); federal minimum wage; estimated fuel efficiency; and spraying speed of a Toro MultiPro 1200 [(3 gal/acre and 9.0 acres/h, respectively (Toro, 2013)]. Frequent mowing is also an important aspect to maintaining high quality turf (Trappe, 2011); therefore, reducing mowing frequency through cultivar selection and PGR application may decrease turf aesthetics.

The objective of this research was to determine if bermudagrass (*Cynodon* spp.) cultivar selection and TE use can significantly reduce the mowing events required to maintain bermudagrass at a 1-inch height with mowing frequency based on the one-third rule without compromising turfgrass aesthetics. Findings from this research are applicable to golf course roughs, as well as commercial, residential, sports and municipal turfgrass areas, resulting in substantial reductions in labor cost, fuel consumption and greenhouse gas emissions.

Field Research

Field research was initiated at Woodruff Farms, Abraham Baldwin Agricultural College, Tifton, GA, on 11 Apr. 2011. Experimental design was a randomized complete strip-block design with three replications. The experimental area was 3600 ft² and contained 36 total plots (individual plot size was 100 ft²) established on a loamy sand (Tifton loamy sand; pH 5.3). Factors included year (2011 and 2012), bermudagrass cultivar [improved common types (*Cynodon dactylon*) as well as hybrid crosses (*Cynodon dactylon* × *C. transvaalensis*)] and monthly TE applications (compared to an untreated control). Improved common bermudagrass cultivars included ‘Discovery’ and ‘Celebration’, while hybrids included ‘Patriot’, ‘TifGrand’, ‘Tifway’ and DT-1 (an experimental hybrid).

Prior to the initiation of research, the experimental area was stripped of the existing sod and fumigated with methyl-bromide (TriEst Ag Group, Inc., Tifton, GA). Bermudagrass sod was laid from 26 to 29 Apr. 2011, depending on the day of delivery. Trinexapac-ethyl was applied the first week of the month in June, July August and September 2011 and 2012 at a rate of 16 fl oz/acre (1.8 fl oz/acre, a.i.). Fertilizer applications of 16N-1.8P-7K (Super Rainbow Plant Food; Agrium U.S. Inc., Denver, CO) were applied at a rate of 0.5 lbs N/1,000 ft² every two weeks from 16 Apr. to 15 Sept. 2011 and 2012, totaling 6.0 lbs N/1,000 ft² per growing season. Irrigation was adjusted throughout the two-year experimental period according to the environmental conditions. During periods of peak annual temperature, July and

August, 0.2 inches of irrigation were applied daily. Individual turfgrass plots were maintained at a 1-inch height with mowing frequency based on the one-third rule (Turgeon, 2008), i.e. when the turf reached 1.5 inches it was mown back down to a one-inch height; turf clippings were returned to their respective plots. A ruler was used to measure the height of the turfgrass every other day, 10 random subsamples per plot. When more than half of the subsamples exceed 1.5 inches the plot was mowed.

August Mowing Events, Turf Quality and Genetic Color

Response variables included August mowing events, turf quality and genetic color. The number of August mowing events required to maintain the turf at a one-inch height with mowing frequency based on the one-third rule was recorded and used to assess mowing frequency. The August mowing events obtained during this research were used to calculate the projected monthly labor hours, fossil fuel consumption and maintenance budget necessary to maintain the various bermudagrass cultivars at a one-inch mowing height with and without the application of TE. Projections on turf treated with TE include the labor hours, fossil fuel and cost to apply the PGR to a 51-acre rough area. Turf quality and genetic color was assessed weekly throughout the months of July and August using the National Turfgrass Evaluation Program (NTEP) system of rating (Morris, 2011). To simplify the presentation of these results, quality and genetic color ratings collected on 24 Aug. 2011 and 2012, which were indicative of the conditions observed throughout the data collection period, are presented. Quality was assessed on a 1–9 scale, with 1 being poorest or dead, 9 being outstanding or ideal, and 6 or above considered acceptable. Quality ratings were a combination of turf density, uniformity, texture and genetic green color. Genetic green color was based on a 1–9 scale with 1 being light green and 9 being dark green (Morris, 2011).

Data were analyzed as a randomized complete strip-block design, with three replications, via PROC MIXED (SAS; ver. 9.1.3, SAS Institute Inc., Cary, N.C.). Factors included year, bermudagrass cultivar and monthly TE use (strip-plot). Mean separations were obtained using Fisher’s least significant difference (LSD) at $P = 0.05$. Main effect of year, and the year-by-bermudagrass cultivar and year-by-TE interactions for all response variables (the number of August mowing events, turf quality and genetic color) were not significant ($P > 0.05$); therefore, the data were pooled across years (Table 1).

Effects of Bermudagrass Cultivar and TE Use on Mowing Frequency

A significant bermudagrass cultivar by TE interaction on the number of August mowing events was observed (Table 1). ‘Discovery’ bermudagrass treated with TE required the lowest number of mowing events to maintain the turf at a 1.0 inch height throughout the month of August, followed by ‘Discovery’ without TE, as well as ‘Celebration’, ‘TifGrand’, and ‘Tifway’ treated with TE (Fig. 1). ‘Celebration’, ‘TifGrand’, and ‘Tifway’ without TE, as well as ‘Patriot’ and DT-1 with or without TE required the greatest number of mowing events to maintain the turf at a 1-inch height. The number of mowing events required to maintain ‘Discovery’, ‘Celebration’, ‘TifGrand’, and ‘Tifway’ bermudagrass at a one-inch height throughout the month of August was reduced by TE by an average of 46%, but the TE had no significant effect on the mowing frequency requirement of

Table 1. Effects of bermudagrass cultivar and trinexapac-ethyl (TE) applications on August mowing frequency turf quality and turf color in Tifton, GA, Aug. 2011 and 2012.

Source of variation	Num DF	Den DF	August mowing events	Pr > F	
				Turf quality	Turf color
Cultivar (C)	5	10	***	***	***
TE ^z	1	48	***	***	*
C x PGR	5	48	**	**	ns

^zTE applications were made monthly in June, July, Aug., and Sept. 2011 and 2012 at a rate of 16 fl oz/acre (1.8 fl oz/acre, a.i.).

* Significant at $P = 0.05$.

** Significant at $P = 0.01$.

*** Significant at $P = 0.001$.

ns Not significant at $P = 0.05$.

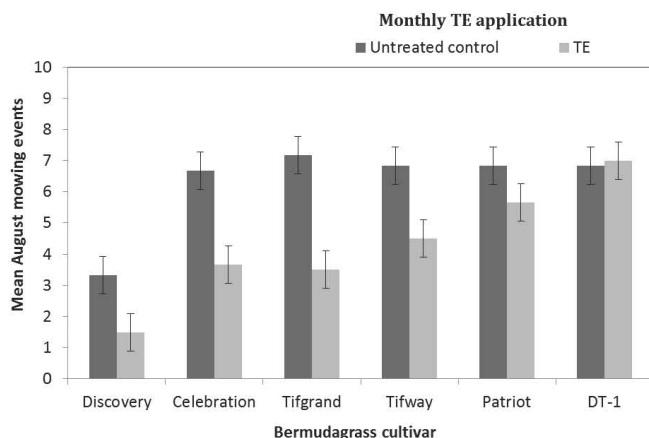


Fig 1. Effects of bermudagrass cultivar by monthly trinexapac-ethyl (TE) applications on the August mowing events necessary to maintain the turf at a 1.0 inch height with mowing frequency based on the one-third rule in Tifton, GA, 2011 and 2012. Trinexapac-ethyl was applied monthly from June to September 2011 and 2012 at a rate of 16 fl oz/acre (1.8 fl oz/acre, a.i.). Mean values of August mowing frequency represent six data points across three replications and two years. Columns with overlapping error bars are not significantly different according to LSD (0.05).

'Patriot' and DT-1 bermudagrass. McCullough et al. (2006) and Fagerness and Yelverton (2010) observed a significant reduction in 'TifEagle' and 'Tifway' bermudagrass, respectively, clipping yield following TE applications. Research conducted in Arkansas determined that ball lie in 'TifSport' bermudagrass maintained at a rough height (1 inch) is often improved by TE applications, which is another reason to consider TE applications (Kowalewski et al., 2012).

Projected Impact on Labor Hours, Fossil Fuel Consumption and Maintenance Budget

The projected labor hours, fossil fuel consumption (a combination of gasoline and diesel) and cost necessary to maintain bermudagrass at a 1-inch height with mowing frequency based on the one-third rule during the month of August varied considerably according to cultivar and TE use (Table 2). The projected labor hours and fossil fuel necessary to spray 'Discovery' bermudagrass with TE and maintain the turf at a 1-inch height was 14.1 h and 38.3 gal, respectively. 'Discovery' bermudagrass maintained without TE required more labor hours and fossil fuel to maintain the turf at a 1-inch height (43.3 h and 65.2 gal). However, when the cost

of applying TE is taken into consideration, it was substantially more expensive to maintain 'Discovery' at a one-inch height when TE was applied (\$2,133) than without TE (\$570). 'Discovery' was maintained at the one-inch height at nearly one-quarter of the cost when TE was not applied. For the remaining cultivars ('Celebration', 'TifGrand', 'Tifway', 'Patriot', and DT-1), it was nearly one-half the cost to maintain the turf without TE.

'Celebration', 'TifGrand', and 'Tifway' bermudagrass treated with TE required an average of 41.1 labor hours and 78.9 gal of fossil fuel (Table 2). Maintaining these cultivars at a one-inch height without TE required more labor and fuel (87 h and 130.8 gal) than when maintained with TE. When considering the cost of maintenance, it was less expensive to maintain these cultivars within a 1-inch height without TE (\$1,144) than with TE (\$2,479).

'Patriot' and DT-1 bermudagrass required the greatest amount of labor (88.5 h) and fossil fuel (133.2 gal) to maintain the turf at a 1-inch height without TE (Table 2). When these cultivars were treated with TE, fewer labor hours and less fossil fuel was required to maintain the turf (68.7 h and 120.4 gal). Both 'Patriot' and DT-1 bermudagrass require more funds to maintain the turf at a one-inch height when treated with TE (\$2,834) than when the cultivars were maintained without TE (\$1,165).

It is important to note that the projected budget necessary to maintain the bermudagrass at a one-inch height includes the cost of the TE product Primo Maxx [\$35 per acre when applied at a rate of 16 fl oz per acre (1.8 fl oz/acre, a.i.)]. Price comparison of Primo Maxx to other TE based products may translate to reductions in TE application costs; therefore, reducing the overall budget necessary for maintaining TE treated areas.

Effects of Bermudagrass Cultivar and TE Use on Turf Quality

The bermudagrass cultivar by TE interaction produced a significant effect on turf quality (Table 1). Monthly applications of TE significantly reduced the turf quality of 'TifGrand', 'Tifway' and DT-1 (Fig 2). Turf quality of 'Discovery', 'Celebration', and 'Patriot' bermudagrass was not affected by TE. 'TifGrand' treated with TE produced the lowest turf quality, while DT-1 without TE produced the highest turf quality, particularly because of the cultivar's superior density, uniformity and fine leaf texture, which was visually observed (Fig. 2). It is important to note that 'Discovery' bermudagrass, with and without TE applications, and 'TifGrand' treated with TE resulted in quality ratings less than 6, which is unacceptable according to NTEP standards when maintained the turf at a one-inch height with mowing frequency based on the one-third rule (Morris, 2011). The authors would also like to note that the reduced turf quality within the 'TifGrand', Tiway and

Table 2. Projected effects of bermudagrass cultivar and trinexapac-ethyl (TE) on August labor hours, fossil fuel consumption and budget to maintain a 51-acre golf course rough area at a one-inch height with mowing frequency based on the one-third rule and monthly applications of TE.

Cultivar	August mowing events		Labor hours ^z		Fossil fuel consumption (gal) ^y		Budget (U.S. dollars) ^x	
	Control	TE	Control	TE	Control	TE	Control	TE
Discovery	3.8	1.3	43.3	14.1	65.2	38.3	\$570.33	\$2,133.25
Celebration	7.4	4.1	83.8	46.1	126.1	86.4	\$1,103.45	\$2,544.20
Patriot	7.8	5.1	88.5	57.4	133.2	103.4	\$1,165.45	\$2,689.24
Tifway	7.7	3.6	86.6	40.5	130.3	77.9	\$1,140.65	\$2,471.67
TifGrand	8.0	3.3	90.4	36.7	136.0	72.3	\$1,190.24	\$2,423.33
DT1	7.8	7.1	88.5	80.0	133.2	137.4	\$1,165.44	\$2,979.31

^z8.0 h to mow and 5.7 h to spray 51 acres mowing 6.4 acres/h using a Groundsmaster 4300-D and spraying 9.0 acres/h using a MultiPro 1200 (Toro Commercial Equipment Guide, 2013a, b).

^y17 gallons of diesel fuel to mow and 17 gal of gasoline to spray 51 acres (Toro Commercial Equipment Guide, 2013a, b).

^x\$124.13 to mow and \$1,785 to spray 51 acres (dollar figures include estimated labor hours, fuel, and PGR product cost); Federal minimum wage \$7.25/h; Estimated price of TE \$35/acre [applied a rate of 16 fl oz/acre (1.8 fl oz/acre, a.i.)]; U.S. average price of diesel \$3.89/gallon and gasoline \$3.67/gal (U.S. Department of Labor, 2013; U.S. Energy Information Administration, 2013).

DT-1 bermudagrass plots treated with TE was observed over 20 d after the final TE application. Therefore, this reduction in turf quality is a result of the reduced mowing frequency produced by TE applications rather than a direct reduction in turf quality caused by application of TE, which is typically observed for a short period of time after TE applications are initiated (Fagerness and Yelverton, 2010).

Similarly to these findings, Lickfeldt et al., 2001, observed decreased TifSport quality as a result of TE applications. Other research has documented an initial reduction in 'Tifway' quality as a result of TE applications (Fagerness and Yelverton, 2010, 16). For instance, Fagerness and Yelverton (Fagerness and Yelverton, 2010) observed decreased quality three weeks after initial TE treatment. This research later observed increased turf quality 17–19 weeks after initial treatment. Regarding turf quality differences between species in scenarios without PGR

applications, Baldwin et al. (Baldwin et al., 2009) determined that 'Celebration' bermudagrass provided greater turf quality than 'Tifway' bermudagrass when grown in shaded conditions. In full sun conditions, quality differences between 'Celebration' and 'Tifway' were not significant, similar to the findings produced by this research.

Effects of Bermudagrass Cultivar and TE Use on Genetic Color

Significant genetic color differences between cultivars were observed, but TE use and cultivar by TE interactions were not significant (Table 1). 'Discovery' bermudagrass produced the darkest genetic green color, followed by 'TifGrand' and 'Tifway', then 'Patriot' and 'Celebration', and finally DT-1 (Table 3). McCullough et al. observed an initial decrease in 'TifEagle' bermudagrass color following TE applications. The turf in this research recovered and the turf color was ultimately enhanced. The research conducted by McCullough et al. (2006) also documented a reduction in 'TifEagle' leaf nutrient concentration and an increase in stolon and rhizome nutrient retention. Fagerness and Yelverton, 2010 observed an initial discoloration of 'Tifway', followed by enhanced green color

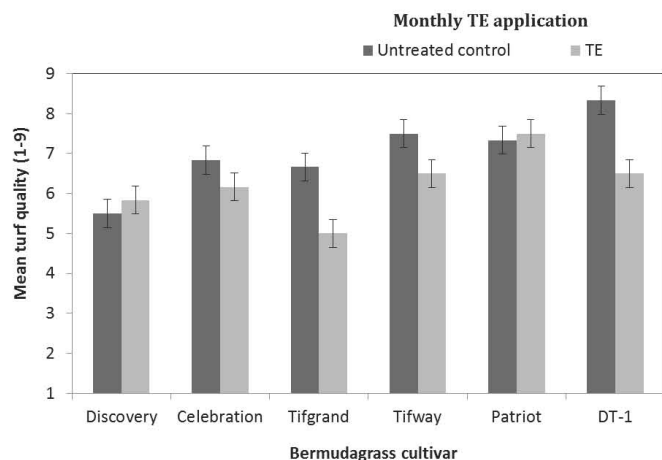


Fig 2. Effects of bermudagrass cultivar by monthly trinexapac-ethyl (TE) applications on turf quality when the turf was maintained at a one-inch height with mowing frequency based on the one-third rule in Tifton, GA, 24 Aug. 2011 and 2012. Trinexapac-ethyl was applied the first week of the month in June, July, August and September 2011 and 2012 at a rate of 16 fl oz per acre (1.8 fl oz per acre, a.i.). Turf quality was assessed on a 1–9 scale, with 1 being dead, 9 being outstanding, and 6 or above acceptable 20 days after the August TE application. Mean values of August mowing frequency represent 6 data points across three replications and two years. Columns with overlapping error bars are not significantly different according to LSD (0.05).

Table 3. Effects of bermudagrass cultivar and trinexapac-ethyl (TE) applications on genetic turf color in Tifton, GA, 24 Aug. 2011 and 2012.

Bermudagrass cultivar	Turf color (1–9) ^a
'Discovery'	8.4 a ^y
'Celebration'	6.6 d
'TifGrand'	7.6 b
'Tifway'	7.3 bc
'Patriot'	6.9 cd
DT-1	5.8 e
Monthly TE applications	
Untreated control	6.9b
TE ^x	7.4a

^aGenetic turf color assessed on a 1–9 scale, with 1 = light green and 9 = dark green 20 d after the August TE application.

^yWithin columns, means followed by the same letter are not significantly different according to LSD (0.05).

^xThe TE applications were made the first week of the month in June, July, Aug., and Sept. 2011 and 2012 at a rate of 16 fl oz/acre (1.8 fl oz/acre, a.i.).

when treated with sequential applications of TE. While DT-1 produced the lowest genetic color, this cultivar had exceptional density, uniformity, and texture resulting in the high turf quality rating despite the low genetic color rating. These findings bring into question the importance of dark green genetic color when comparing differences between cultivars.

Conclusions

Turf managers hoping to reduce mowing frequency requirement, as well as labor hour allocation and fossil fuel consumption, should consider 'Discovery' bermudagrass. However, those planning to utilize 'Discovery' bermudagrass should also consider the low turf quality observed when this cultivar was maintained at a one-inch height with mowing frequency bases on the one-third rule. While the slow vertical growth provided by 'Discovery' bermudagrass may substantially reduce mowing frequency requirements, managers hoping to produce increased ball lie depth in rough areas (to increase difficulty when hitting out of the rough) should select a more aggressively growing cultivar, like 'Patriot' and DT-1 bermudagrass. It is also important to note that 'Discovery' bermudagrass provided the darkest green color rating.

Applications of TE significantly decreased the mowing frequency requirement of 'Discovery', 'Celebration', 'TifGrand', and 'Tifway' bermudagrass. However, the turf quality of 'TifGrand', 'Tifway' and DT-1 bermudagrass was decreased by monthly TE applications. Therefore, those hoping to reduce mowing frequency requirements without sacrificing turf quality can safely apply TE to 'Discovery' and 'Celebration' bermudagrass. The experimental hybrid DT-1, without TE, produced the greatest turf quality and the lowest genetic green color during this study.

It is important to note that mowing frequency, turf quality and genetic color are not the only three parameters to consider when selecting a turf for a designated area and function. Other essential characteristics to consider when selecting turfgrass include, but are not limited to, wear, drought and shade tolerance, as well as wear recovery, which are all common problems in rough areas. Therefore, there is a need for continued research, particularly on the newer cultivars utilized in this project, i.e. 'TifGrand', 'Discovery' and DT-1 bermudagrass.

If managers of golf, commercial, residential, sports and municipal turf maintenance began utilizing slow growing bermudagrass cultivars and TE to decrease mowing frequency requirements, substantial reductions in labor hours, fuel consumption and greenhouse gas emissions would be observed compared to faster growing cultivars. However, TE applications translated to little financial savings and in some instance resulted to greater budget allocations to maintaining the bermudagrass turf in this research at a one-inch height with mowing frequency based on the one-third rule. Price comparison of Primo Maxx to other TE based products may translate to reductions in TE application costs. Turf managers should also realize that turf quality and recovery from devoting and traffic may be compromised by utilizing slow growing cultivars and or PGRs to reduce mowing frequency requirements.

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