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Bermudagrass and Zoysiagrass Cultivar Selection: Part 1, Clipping Yield, Scalping Tendency, and Golf Ball Lie

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Abstract

Bermudagrass (*Cynodon* spp. Rich.) and zoysiagrass (*Zoysia* spp. Willd.) are two of the most commonly used turfgrass species on golf course fairways and tees in the southern United States. However, there are few reports directly comparing commonly used cultivars of bermudagrass to commonly used cultivars of zoysiagrass. The objectives of this research were to quantify the clipping yield, percent ball exposed (ball lie), and to identify the scalping tendency for five bermudagrass and seven zoysiagrass cultivars grown in Fayetteville, AR. The cultivars generally producing the lowest clipping yields were 'Patriot' bermudagrass and 'Meyer' zoysiagrass, while 'Tifway' bermudagrass and 'Palisades' zoysiagrass generally had the highest clipping yields. On most collection dates, *Cynodon* spp. yielded more clippings than *Zoysia* spp. Patriot bermudagrass had the highest scalping tendency across the two years of this study. The cultivars Patriot, 'Riviera,' 'Tifsport,' and Tifway bermudagrass as well as Meyer and Diamond zoysiagrass had the best ball lie in unmown (five days after mowing) conditions, while Palisades zoysiagrass had the poorest ball lie in unmown conditions. Ball lie was similar for all cultivars immediately following mowing. These studies identified cultivars of bermudagrass and zoysiagrass that have improved clipping yields, scalping tendencies, and golf ball lie.

Introduction

Bermudagrass (*Cynodon* spp.) and zoysiagrass (*Zoysia* spp.) are the predominant turfgrass species used on golf course fairways and tees in Arkansas (30). Across the transition zone and southern United States, bermudagrass is the most commonly used turfgrass on fairways and tees (24), and bermudagrass and zoysiagrass are adapted to the transition and warm humid, climatic zones (4). Bermudagrass and zoysiagrass are desirable species for golf course fairways and tees due to their deep rooting, disease resistance, recovery potential, drought, heat, wear, traffic, and low mowing height tolerance (3,38,39,40).

Several studies have reported differences of growth rate between bermudagrass and zoysiagrass. Patton et al. (31) determined that bermudagrass was faster to establish from seed than zoysiagrass. Volterrani et al. (41) and Busey and Myers (9) reported a faster vegetative establishment for bermudagrasses than zoysiagrasses. Trappe et al. (39) reported both similarities and differences in divot recovery for various bermudagrass and zoysiagrass cultivars. Several important aspects of golf course management can be influenced by growth rate, including clipping yield, scalping tendency, and golf ball lie (6,11,16).

Differences in growth rate have been reported between bermudagrass and zoysiagrass (6,13,14). Beard et al. (6) reported variations in leaf extension rates among bermudagrass genotypes, and concluded that this variation would

require adjustment of mowing frequency between cultivars. Although some reports (6,13,14) document differences in leaf extension rates of species or cultivars, other work (21) shows little difference among species or cultivars. Kim and Beard (21) investigated the vertical leaf extension rate of 'Arizona Common' bermudagrass, Tifway bermudagrass, and Meyer zoysiagrass in the greenhouse and reported no differences among these cultivars. However, more research is needed comparing clipping yields for commonly used cultivars of bermudagrass and zoysiagrass.

Species or cultivars that require less maintenance, such as reduced mowing frequency, are becoming more desirable to turfgrass managers (33). Research documenting differences in clipping yield among cultivars and species would allow superintendents to choose a cultivar that could facilitate a reduced frequency for mowing and possibly reduced use of plant growth regulators. These cultivars could help to reduce equipment wear, labor, and fuel costs associated with maintaining golf course fairways and tees or sports fields.

Scalping has been defined as "the removal of an excessive quantity of green shoots from a turf at any one mowing that results in a stubby, brown appearance due to the exposed stems, stolons, and dead lower leaves" (5). While Beard and Beard (5) cite the aesthetic damage scalping incurs on a turfgrass sward, it can also affect plant health (1,8,29,34). Faster growth rates of some species and cultivars increase thatch production, which could promote scalping (11). In addition to excessive thatch accumulation, other potential causes of scalping may include mower adjustment errors, infrequent mowing, or an uneven soil surface (10). In general, scalping also disrupts a consistent playing surface that is necessary for golfing.

Differences in bermudagrass and zoysiagrass cultivar susceptibility to scalping have been reported. Across two locations rating for bermudagrass scalping tendency, Patriot was rated to be the most susceptible to scalping, with 'Princess 77' and Tifway having moderate scalping damage and Riviera and Tifsport as having minimal scalping (28). In a separate study evaluating scalping tendency of zoysiagrass cultivars in California, 'Zenith' was more susceptible to scalping than El Toro, Meyer, and 'Zorro' in May and June but similar in scalping tendency in other months (27). Hale (15) reported that 'Royal' and 'Cavalier' zoysiagrass were more prone to scalping under higher rates of N (≥ 192 kg/ha/year). These works evaluated scalping tendency within species. However, little research has evaluated scalping tendency among multiple species.

The position at which a golf ball comes to rest in a turf canopy influences how a golfer will attempt their next shot. A golf ball that rests on top of the canopy provides golfers increased control over golf shots (23). Beard (4) cited turfgrass species, cultivar, and shoot density as determining factors for ball lie. Others have also stated zoysiagrass provides a good golf ball lie for players to take their shot (7,17).

Researchers at the University of Arkansas recently developed a method to measure golf ball lie using digital image analysis (36). Little differences among cultivars of bermudagrass and zoysiagrass were reported for plots mown at 1.25 cm, but some differences in golf ball lie were observed for plots mown at 2.5 cm (36). Other work has evaluated the specific management practices that affect ball lie in bermudagrass (16,25), but none have attempted to quantify differences in ball lie among bermudagrass and zoysiagrass cultivars.

There are few reports comparing commonly used cultivars of bermudagrass to commonly used cultivars of zoysiagrass and a need exists to evaluate cultivars across species in direct comparison experiments. The objectives of this research were to: (i) quantify clipping yield; (ii) identify scalping tendency; and (iii) quantify golf ball lie for several bermudagrass and zoysiagrass cultivars commonly used on golf course fairways and tees.

Evaluating Clipping Yield, Scalping Tendency, and Golf Ball Lie

This experiment was conducted at the Arkansas Agricultural Research and Extension Center, in Fayetteville, AR (36°06'N, 94°10'W, 384 m). The planting site was fumigated with methyl bromide at 549 kg/ha on 17 April 2007 and was

a Captina silt-loam soil (fine-silty mixed mesic Typic Fragiudalt) with a pH of 6.6, 1% organic matter, 105 kg P/ha, and 97 kg K/ha. Five cultivars of bermudagrass and seven cultivars of zoysiagrass were used in the experiment (Table 1). Cultivar selection was based on use and availability in the transition zone and southern United States. All cultivars were established as sod in July 2007 as 1.8-m by 1.8-m plots with a 0.3-m border maintained to prevent contamination from adjacent plots. Due to limited sod availability, 'Diamond' zoysiagrass was initially planted as 0.5-m by 0.5-m plots until additional plant material could be propagated. Diamond plugs were planted in May 2008 in the remainder of the plot area and plots were fully established by August 2008.

Table 1. Cultivars, experimental notation, and species of bermudagrass and zoysiagrass used in this study.

Cultivar	Experimental notation	Species
Cavalier	DALZ8507	<i>Zoysia matrella</i> (L.) Merr.
Diamond	DALZ8502	<i>Zoysia matrella</i> (L.) Merr.
El Toro	UCR#1	<i>Zoysia japonica</i> Steud.
Meyer	Z-52	<i>Zoysia japonica</i> Steud.
Palisades	DALZ8514	<i>Zoysia japonica</i> Steud.
Patriot	PKC 18-4	<i>Cynodon dactylon</i> (L.) Pers. × <i>C. transvaalensis</i> Burt-Davy
Princess 77	FMC-77, SWI-77*	<i>Cynodon dactylon</i> (L.) Pers. var. <i>dactylon</i>
Riviera	OKS 95-1	<i>Cynodon dactylon</i> (L.) Pers. var. <i>dactylon</i>
Tifsport	Tift 94	<i>Cynodon dactylon</i> (L.) Pers. × <i>C. transvaalensis</i> Burt-Davy
Tifway	Tifton 419	<i>Cynodon dactylon</i> (L.) Pers. × <i>C. transvaalensis</i> Burt-Davy
Zenith	ZNW-1	<i>Zoysia japonica</i> Steud.
Zorro	DALZ8510, DALZ9601*	<i>Zoysia matrella</i> (L.) Merr.

* The cultivars Princess 77 bermudagrass and Zorro zoysiagrass were each evaluated using two experimental notations before the cultivars were released for commercial use.

All experimental areas were maintained under typical golf course fairway conditions, with a mowing height of 1.3 cm. All plots were fertilized with nitrogen using urea (46-0-0) at 24 kg/ha per growing month for zoysiagrass and 49 kg/ha per growing month for bermudagrass based on input from Arkansas golf course superintendents. The experimental design was a randomized complete block design with four replications.

Clipping yield was measured on 4 and 28 August and 23 September 2008 as well as on 4 June, 13 July, and 31 August 2009. The area of each plot from where clippings were collected was measured prior to each collection and recorded to provide a total dry weight per unit area measurement. A Jacobsen Greensking (Textron Co., Charlotte, NC) mower was used to collect clippings and two passes (opposite directions) were made on the same area of the plot to ensure complete clipping collection. Clippings were collected when all plots grew to a height of at least 1.9 cm, which occurred approximately five days after the previous mowing. Clippings were harvested after morning dew had evaporated and placed in an oven at 80°C for four days prior to measuring dry weight.

Scalping was measured on 4 and 28 August and 23 September 2008 as well as on 4 June, 13 July, and 31 August 2009. Mowing was performed as described above for clipping yield. Digital images were taken immediately prior to mowing and again immediately after mowing using a digital camera (Olympus, SP-510UZ, Center Valley, PA). A portable light box similar to that described in Ikemura (18) was used to provide a consistent light source for collecting images. Each image was analyzed for percent green turf cover using SigmaScan Pro 5

software (Systat Software Inc., Richmond, CA) using techniques described by Richardson et al. (35). The amount of turf scalped (%) was calculated as: $100 * [(\text{percent green turf before mowing} - \text{percent green turf after mowing}) / \text{percent green turf before mowing}]$.

Golf ball lie was measured on 7 July and 28 August 2008 as well as 13 July and 31 August 2009. Ball lie was evaluated five days after mowing to simulate unmown conditions and immediately after mowing (< 1 h) for mown conditions. Ball lie was also evaluated on 17 March 2009 and 18 March 2010 for dormant, unmown conditions. Three golf balls were randomly rolled onto each plot on each date and each golf ball was considered a subsample. The percent ball exposed above the canopy was measured using a device developed at the University of Arkansas and the methods described by Richardson et al. (36) for each of the three subsamples. For discussion purposes, a ball lie $\geq 90\%$ was deemed acceptable for playability.

Data for clipping yield, scalping tendency, and golf ball lie were analyzed using PROC GLM (SAS Institute Inc., Cary, NC). When analyzing golf ball lie, the appropriate *F*-tests were conducted using block by cultivar or species as the subsampling error term and the denominator. Data were analyzed for collection date by cultivar or species interactions. Cultivar and species means were separated using Fisher's protected least significant difference when *F* tests were significant at $P < 0.05$.

Clipping Yield Differences Among Cultivars and Species

Differences existed among cultivars and species of bermudagrass and zoysiagrass for clipping yield in both years of the study, and in 5 of the 6 dates for the dry weight of clippings collected (Table 2).

In 2008, there were differences among cultivars for clipping yield on two of three sampling dates. Princess 77 and Tifway bermudagrass had the highest clipping yield on 4 and 28 August 2008, while Palisades zoysiagrass was among the cultivars with the highest clipping yield on 4 August. Meyer and Zorro zoysiagrass had the lowest clipping yield on 4 and 28 August 2008 (Table 2). Differences also existed among species. Both *C. dactylon* and *C. dactylon* \times *C. transvaalensis* had similar clipping yields throughout 2008, and had higher clipping yields than *Z. japonica* and *Z. matrella* in 2008. *Zoysia japonica* and *Z. matrella* had similar clipping yields in 2008, except on 4 August, in which *Z. japonica* had a higher clipping yield than *Z. matrella*.

Similar to 2008 data, differences existed in clipping yield trends among collection dates in 2009 (Table 2). Cultivars with the highest clipping yields on 4 June and 31 August 2009 were El Toro, Palisades, Zenith, and Zorro zoysiagrass and those cultivars with the lowest clipping yields were Patriot, Princess 77, Tifsport, and Tifway bermudagrass (Table 2). On 13 July 2009, Tifway and Tifsport bermudagrass produced the highest clipping yields, whereas Meyer zoysiagrass had the lowest clipping yield, which was similar to August 2008 data. *Zoysia* spp. produced more clippings than *C. dactylon* \times *C. transvaalensis* in early summer (4 June), but *Z. matrella* produced similar clipping yields to *C. dactylon*. In late summer (31 August), *Zoysia* spp. yielded more clippings than *Cynodon* spp., while *Cynodon* spp. yielded more clippings than *Zoysia* spp. in the middle of summer (13 July). Similar to 2008 data, *C. dactylon* and *C. dactylon* \times *C. transvaalensis* had similar clipping yields throughout 2009.

Clipping yield varied by cultivar and collection date in 2009. For example, Tifsport and Tifway yielded few clippings in early and late summer 2009, while in middle summer they yielded the highest amount of clippings. Conversely, Zenith zoysiagrass had the highest clipping yield in early and late summer, but in the middle summer it yielded one of the lowest amounts of clippings. It is unclear why clipping yield varied across collection dates for some cultivars, but may emphasize the need for future clipping yield research to include seasonal collection dates.

Table 2. Clipping yield (dry weight) means across three dates in both 2008 and 2009 for various bermudagrass and zoysiagrass cultivars grown in Fayetteville, AR.

Cultivar	Species	2008			2009		
		4 Aug	28 Aug	23 Sep	4 Jun	13 Jul	31 Aug
		Clipping yield (%) ^x					
Cavalier	ZM ^y	4.9 fg ^z	4.9 cd	7.1	8.7 cd	18.6 cd	10.9 a
El Toro	ZJ	7.5 de	7.3 b	8.3	12.6 a	18.4 cd	10.3 ab
Meyer	ZJ	3.1 h	4.4 d	6.5	8.6 cd	8.7 f	8.5 bc
Palisades	ZJ	10.3 ab	7.6 b	8.6	11.2 ab	19.5 c	11.2 a
Patriot	CDCT	8.8 bcd	7.6 b	7.1	5.8 ef	20.8 cd	6.1 d
Princess 77	CD	10.8 a	9.8 a	9.2	3.9 f	21.3 bc	6.5 d
Riviera	CD	8.6 cd	8.1 ab	7.2	10.1 bc	18.5 cd	5.3 d
Tifsport	CDCT	9.2 bc	7.7 b	7.3	5.6 ef	25.2 ab	6.6 cd
Tifway	CDCT	10.2 ab	8.0 ab	6.1	5.4 ef	28.0 a	4.8 d
Zenith	ZJ	6.0 ef	6.3 bc	7.3	10.6 abc	13.6 e	9.5 ab
Zorro	ZM	4.4 gh	5.4 cd	8.0	10.5 abc	19.4 c	10.6 a
Source							
Cultivar		<0.0001	<0.0001	NS	<0.0001	<0.0001	<0.0001
Species							
<i>C. dactylon</i>	CD	9.7 a	9.0 a	8.2	7.0 bc	24.6 a	5.9 b
<i>C. dactylon</i> x <i>C. transvaalensis</i>	CDCT	9.4 a	7.7 a	7.7	5.6 c	39.9 a	5.8 b
<i>Z. japonica</i>	ZJ	6.7 b	6.4 b	7.5	10.8 a	15.1 c	9.9 a
<i>Z. matrella</i>	ZM	4.7 c	5.1 b	6.8	8.8 b	17.4 bc	9.6 a
Source							
Species		<0.0001	<0.0001	NS	<0.0001	<0.0001	<0.0001

^x Clipping yield of cultivars expressed as weight per unit area.

^y ZM = *Zoysia matrella*; ZJ = *Zoysia japonica*; CDCT = *Cynodon dactylon* x *C. transvaalensis*; CD = *Cynodon dactylon*.

^z Values in a column followed by the same letter are not significantly different from another (LSD, $\alpha = 0.05$).

Due to limited work on clipping yield of bermudagrass and zoysiagrass, it is difficult to compare clipping yield results in this study with previous research. The clipping yield rankings of zoysiagrass cultivars were similar to previous rankings on the establishment rate, stolon growth rate, and divot recovery of zoysiagrasses (20,32), where Palisades, El Toro, and Zenith had faster growth than Meyer. Although there were differences among bermudagrass cultivars across collection dates for clipping yield, they generally all had similar clipping yields. This is similar to previous rankings of divot recovery for bermudagrass cultivars (19).

Although these data were able to identify differences in clipping yield among cultivars of bermudagrass and zoysiagrass, they do not provide estimates for how clipping yield relates to mowing frequency or leaf extension rate. Patton et al. (32) reported differences in specific leaf area among zoysiagrass cultivars. This demonstrates that leaf mass per surface area varies among cultivars and therefore clipping data alone may not provide a complete picture on which cultivars have a faster growth rate, or plants that require an increased mowing frequency. More research should be performed to correlate clipping yields and other parameters such as leaf extension rate to mowing frequency requirements to more adequately provide recommendations to turfgrass managers. Based upon these results, the cultivars producing the lowest clipping yields were

Patriot bermudagrass and Meyer zoysiagrass, while the cultivars producing the highest clipping yields, Tifway bermudagrass and Palisades zoysiagrass, should be avoided if low clipping yield is desired.

Differences in Scalping Tendency

Differences existed among bermudagrass and zoysiagrass cultivars for the amount of scalping on 4 of the 6 collection dates (Table 3). Scalping rankings were similar among cultivars in both years of the study, with the exception of Tifsport bermudagrass having increased scalping on 31 August 2009 and not in 2008. Patriot bermudagrass had more scalping in 2008 than the other 11 cultivars across the three sampling dates (Table 3), although scalping was < 3% on the first two collection dates. Patriot and Tifsport bermudagrass were more prone to scalping on 31 August than other cultivars in 2009 (Table 3). *Cynodon dactylon* × *C. transvaalensis* consistently had more scalping than other species for both 2008 and 2009, but this was heavily influenced by Patriot and Tifsport. One clear trend in scalping across years was an increase in bermudagrass scalping for specific cultivars in late summer and early autumn compared to other collection dates. This agrees with Morris (26) in which bermudagrass tended to have greater scalping in September than in August. It was unclear why Patriot bermudagrass scalped more than other cultivars, but it may be because of Patriot's aggressive growth rate and high shoot density (19,28,37). Another possible explanation may be due to shortening of daylength and Patriot's susceptibility to decreased light intensity (2,40).

Zoysiagrasses in general are less likely to scalp because of their increased chlorophyll content in lower leaves compared to bermudagrass (8). Field and greenhouse observations suggest that zoysiagrasses produce leaves lower in the canopy than bermudagrasses, making the actively growing part of the plant less exposed to scalping. This theory is supported by the work of Biran and Bushkin-Harav (8) and may provide an explanation as to why bermudagrass cultivars such as Patriot and Tifway are more prone to scalping than zoysiagrass.

One observation worth mentioning was the lack of similarities between the cultivars having higher clipping yields with the cultivars having low tendencies to scalp. The cultivars with the highest tendency to scalp were among cultivars with the lowest clipping yields. This is surprising because cultivars having higher clipping yields would be expected to have faster growth rates, which are associated with species or cultivars more prone to scalping.

The range for scalping tendency for all cultivars across all dates was from 0 to 15.6%. While there were statistical differences between cultivars and species, it is unclear how much of an increase in scalping tendency will affect playability and overall plant health, or what percentage scalping is considered tolerable by most golf course superintendents. Future research should be performed to identify the effect of scalping on playability and overall plant health in warm-season turf, as this would be beneficial for turfgrass managers. Based on these results, turfgrass managers concerned with scalping tendency of their playing surface should avoid planting Patriot and Tifsport bermudagrass, increase mowing frequency in late summer, or apply trinexapac-ethyl to reduce scalping (11).

Table 3. Percent scalping tendency for three dates in 2008 and 2009 for various bermudagrass and zoysiagrass cultivars grown in Fayetteville, AR.

Cultivar	Species	2008			2009		
		4 Aug	28 Aug	23 Sep	4 Jun	13 Jul	31 Aug
		Scalping tendency (%) ^x					
Cavalier	ZM ^y	0.0 b ^z	0.3 b	0.1 b	2.0	0.3	0.0 b
Diamond	ZM	0.2 b	0.1 b	0.0 b	2.8	0.7	0.0 b
El Toro	ZJ	0.1 b	0.5 b	0.7 b	2.7	0.0	0.0 b
Meyer	ZJ	0.3 b	0.0 b	0.3 b	11.0	0.2	0.0 b
Palisades	ZJ	0.0 b	0.1 b	0.4 b	1.8	1.3	0.0 b
Patriot	CDCT	0.8 a	2.4 a	15.6 a	1.8	0.0	13.3 a
Princess 77	CD	0.1 b	0.4 b	0.3 b	6.2	0.1	1.2 b
Riviera	CD	0.1 b	0.5 b	0.4 b	5.8	0.0	0.1 b
Tifsport	CDCT	0.2 b	0.4 b	1.4 b	0.1	0.7	12.0 a
Tifway	CDCT	0.3 b	0.2 b	7.2 b	6.4	0.8	0.3 b
Zenith	ZJ	0.1 b	0.0 b	0.3 b	1.6	0.2	0.0 b
Zorro	ZM	0.0 b	0.0 b	0.1 b	3.8	0.5	0.0 b
Source							
Cultivar		0.031	0.01	0.005	NS	NS	<0.0001
Species							
<i>C. dactylon</i>	CD	0.1 b	0.7 ab	0.3 b	6.0 a	0.5 a	0.6 b
<i>C. dactylon</i> × <i>C. transvaalensis</i>	CDCT	0.4 a	1.0 a	8.1 a	2.8 a	0.1 a	8.5 a
<i>Z. japonica</i>	ZJ	0.1 b	0.0 b	0.4 b	2.8 a	0.4 a	0.0 b
<i>Z. matrella</i>	ZM	0.1 b	0.1 b	1.0 b	2.9 a	0.5 a	0.0 b
Source							
Species		NS	0.0027	0.0099	NS	NS	0.0004

^x Scalping tendency expressed as a percent using the equation [100*(initial green cover – post green cover)/(initial green cover)].

^y ZJ = *Zoysia japonica*; ZM = *Zoysia matrella*; CD = *Cynodon dactylon*; CDCT = *Cynodon dactylon* × *C. transvaalensis*.

^z Values in a column followed by the same letter are not significantly different from another (LSD, $\alpha = 0.05$).

Ball Lie as Affected by Cultivar and Species

Differences existed among cultivars and species of bermudagrass and zoysiagrass for ball lie (percent ball exposed) in unmown and dormant conditions for both years of the study (Table 4, Fig. 1). There were no differences among cultivars and species for ball lie when measured immediately following mowing and ball lie was > 90% for all cultivars in closely mown turf (data not shown). On 28 August 2008, Patriot, Princess 77, Riviera, Tifsport, and Tifway bermudagrass as well as Cavalier, Diamond and Meyer zoysiagrass had the best ball lie in unmown conditions, while Palisades had the worst ball lie (Table 4, Fig. 1). Additionally, there were differences among cultivars for ball lie in dormant conditions on 17 March 2009, but all cultivars had ball lie > 92% (Fig. 1).

Table 4. Ball lie (percent ball exposed) for bermudagrass and zoysiagrass cultivars in unmown conditions for four dates in 2008 and 2009 as well as two dates in March (untrafficked, dormant conditions) in 2008 and 2009 in Fayetteville, AR.

Cultivar	Species	2008		2009			2010
		7 Jul	28 Aug	17 Mar	13 Jul	31 Aug	18 Mar
		Ball lie (%) ^x					
Cavalier	ZM ^y	89	86 abc ^z	92.8 d	82 ab	82 c	92.0 a-d
Diamond	ZM	91	89 ab	93.1 bcd	77 ab	87 abc	93.9 abc
El Toro	ZJ	89	88 ab	92.9 cd	72 b	82 c	92.2 a-d
Meyer	ZJ	87	87 abc	92.8 d	87 a	84 abc	90.2 b-e
Palisades	ZJ	88	76 d	91.9 d	59 c	70 d	86.7 e
Patriot	CDCT	89	91 a	95.6 a	79 ab	89 abc	93.9 abc
Princess 77	CD	90	85 abc	93.9 a-d	74 b	83 bc	95.7 a
Riviera	CD	88	89 ab	94.9 abc	81 ab	86 abc	94.4 ab
Tifsport	CDCT	90	88 ab	93.9 a-d	78 ab	92 a	95.5 a
Tifway	CDCT	90	92 a	95.1 ab	77 ab	91 ab	95.8 a
Zenith	ZJ	89	80 cd	92.9 cd	78 ab	82 c	89.9 cde
Zorro	ZM	88	82 bcd	93.4 bcd	72 b	83 c	88.7 de
Source of variation							
Cultivar (C)		NS	0.0051	0.0293	0.0013	0.0007	0.0007

^x Ball lie expressed as percent ball exposed

^y ZM = *Zoysia matrella*; ZJ = *Zoysia japonica*; CDCT = *Cynodon dactylon* × *C. transvaalensis*; CD = *Cynodon dactylon*.

^z Values in a column followed by the same letter are not significantly different from another (LSD, $\alpha = 0.05$).



Fig. 1. Golf ball lie for 'Diamond' and 'Palisades' zoysiagrass under mown, unmown, and dormant simulated golf course fairway conditions.

In 2009, Patriot, Tifsport, and Tifway bermudagrass and Diamond and Meyer zoysiagrass had the best ball lie in July and August (Table 4). Palisades zoysiagrass had the poorest ball lie in July and August 2009. Similar to 17 March 2009 data, there were differences in ball lie in dormant conditions on 18 March 2010. However, Palisades, Zenith, and Zorro zoysiagrasses each had ball lies < 90%. Cultivar rankings for ball lie were similar when measured at various timings in July and August in the summer or when the turf was dormant.

Ball lie varied by date for each species (Table 5). *Cynodon dactylon* × *C. transvaalensis* had the best ball lie in August, although it was similar to *C. dactylon* and *Z. matrella* in July. *Zoysia matrella* had similar ball lie to *C. dactylon* across both collection periods. *Cynodon dactylon* had a similar ball lie to *Z. japonica* in July, but they were different in August.

The findings of Richardson et al. (36) at 1.3 cm and at 2.5 cm are very similar to the overall trends in golf ball lie in our experiment of bermudagrass cultivars in mown conditions (1.3 cm) and in unmown conditions (~2.0 cm). Richardson et al. (36) also reported an analysis by species, and concluded that *C. dactylon* × *C. transvaalensis* had a superior ball lie to *C. dactylon* at a mowing height of 2.5 cm. This somewhat agrees with ball lie results of unmown conditions of this research, where *C. dactylon* × *C. transvaalensis* had superior ball lie compared to *C. dactylon* in August, but the two species were similar in July (Table 5).

Similar trends existed between unmown ball lie in our research and that reported in Richardson et al. (36) on zoysiagrass ball lie, where Meyer had superior ball lie to Palisades at a mowing height of 2.5 cm. Additionally, Richardson et al. (36) determined that no differences ($P < 0.05$) occurred between *Zoysia* spp., which was similar to our findings (Table 5).

Although differences existed among cultivars and species on dormant turf (Table 5), all cultivars and species except Palisades, Zenith, and Zorro zoysiagrass (86.7-89.9%) had ball lies >90%. However, for discussion purposes, there is likely little agronomic difference between 86.7% and 90% and thus all cultivars and species tested had a good ball lie in dormant conditions.

Table 5. Ball lie (percent ball exposed) for *Cynodon* and *Zoysia* spp. in unmown conditions for two dates in July (7 July 2008 and 13 July 2009) and August (28 August 2008 and 31 August 2009) in Fayetteville, AR.

		July	August
		Ball lie (%) ^x	
Species	<i>C. dactylon</i>	83 BC ^y	86 B
	<i>C. dactylon</i> × <i>C. transvaalensis</i>	84 B	91 A
	<i>Z. japonica</i>	81 CD	80 D
	<i>Z. matrella</i>	83 BC	84 B
Source of variation	Year (Y)	0.0015	
	Species (S)	<0.0001	
	S × Y	NS	
	Date (D)	0.0003	
	D × Y	<0.0001	
	S × D	0.0002	
	S × D × Y	NS	

^x Ball lie expressed as percent ball exposed.

^y Values across rows or columns followed by the same letter are not significantly different from another (LSD, $\alpha = 0.05$).

Anecdotal observations that zoysiagrass has a superior ball lie were made by individuals in the transition zone and were likely made in comparison to cool-season turf such as perennial ryegrass or in comparison to common

bermudagrass (7,12,17,22). Our research shows that bermudagrasses and zoysiagrasses generally produce a similar ball lie in maintained fairway turf although ball lie is more variable in taller turf.

More research is needed to correlate the percent of ball exposed to the difficulty of a golf shot. Although Lowe (23) suggests that a golf ball resting on the top of the canopy is preferred by good golfers, he also acknowledges that the average golfer may prefer a different lie. More research on golf ball lie will allow superintendents to select cultivars or species to meet the needs of their players and the difficulty of the playing conditions on the course. Golf ball lie can be maximized in unmown conditions using bermudagrass cultivars Tifsport, Tifway, and Patriot bermudagrass, or Meyer zoysiagrass.

Summary

The clipping yields of species and cultivars were strongly influenced by collection date. The cultivars typically with the lowest clipping yield were Patriot bermudagrass and Meyer zoysiagrass, while Tifway bermudagrass and Palisades zoysiagrass had the highest amount of clippings. Patriot bermudagrass had the highest scalping across the two years of this study, but this occurred only in late summer of each year. The cultivars Patriot, Riviera, Tifsport, and Tifway bermudagrass, and Meyer and Diamond zoysiagrass had the best ball lie in unmown conditions, while Palisades had the poorest ball lie in unmown conditions. These results along with data on traffic tolerance (40) and divot resistance (38) and recovery (39) will assist golf course superintendents in selecting cultivars of bermudagrass and zoysiagrass well-adapted for golf course fairways or tees that contain low clipping yields and scalping tendencies as well as a good golf ball lie in order to help to reduce plant growth regulator use, equipment wear, and labor and fuel costs associated with maintaining a golf course turf.

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