Overseeding and Trinexapac-ethyl Effects on Tolerance to Simulated Traffic of Four Bermudagrass Cultivars Grown as a Sand-based Athletic Field

Michael T. Deaton[1] and David W. Williams

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Summary. Common bermudagrass (*Cynodon dactylon*) and hybrid bermudagrass (*Cynodon dactylon* var. *dactylon* × *C. transvaalensis*) often are used for athletic fields as a result of their wear tolerance and recuperative ability. A wear tolerance study was conducted May 2007 through Nov. 2008 in Lexington, KY. Plots were managed as athletic turf and simulated traffic was applied during the Kentucky high school football seasons. The cultivars Quickstand, Tifway 419, Riviera, and Yukon grown in a sand-based medium were evaluated. Trinexapac-ethyl (TE) was applied at label rates and frequencies or left untreated. Overseeding treatments were perennial ryegrass (*Lolium perenne*) at 0, 546, and 1093 lb/acre pure live seed. Traffic treatments were applied with a Brinkman traffic simulator three times per week, once each Monday, Wednesday, and Friday, without regard to soil moisture status or weather for the periods 10 Sept. to 2 Nov. 2007 and 12 Sept. to 14 Nov. 2008. In both years of the study, the main effect of cultivar was significant ($P < 0.05$) in traffic tolerance ('Tifway 419' = 'Riviera' > 'Quickstand' = 'Yukon'). Overseeding at the medium and high rates also provided significantly greater turf cover for the coarse-textured, more open cultivars (Quickstand and Yukon) over the fine-textured, more dense cultivars (Riviera and Tifway 419). Applications of TE did not significantly improve tolerance to simulated athletic traffic in either year of the study regardless of cultivar or overseeding treatment. Within the parameters of this study, data indicate that only cultivar has significant effects on tolerance to simulated traffic on a sand-based field. Overseeding treatments for the fine-textured, more dense cultivars and TE applications on sand-based field systems had no positive significant effects on tolerance to simulated traffic.

Sand-based athletic fields hold several distinct advantages over native soil root zones. The consistent particle size, high porosity and infiltration rates, and resistance to compaction make sand-based systems one of the best growing mediums for turfgrass playing surfaces (Xiong et al., 2006). The U.S. Golf Association recommendations set the standard for putting green construction that allows for optimum playing conditions while maintaining acceptable appearance and tolerating traffic while resisting compaction (Xiong et al., 2006). This widely adopted method of construction allows for better drainage to increase the field use capacity.

Increased capacity for field events on sand-based systems makes wear tolerance an important issue. Wear tolerance of a particular field will be greatly influenced by the root zone. Soil characteristics that promote or resist compaction will directly influence plant health and wear tolerance (Beard, 1973). Most of the recent investigations in this area have been conducted in native soils. In addition to their many advantages, sand-based systems also have some disadvantages. Improved drainage provided by the sand root zone encourages healthy turfgrass growth; however, surface instability becomes an issue when turfgrass cover is lost (Sherratt et al., 2005). Divoting occurs from different mechanical forces that tear and remove a section of turf. Surface stability and tolerance to these stresses become an issue as a result of the inherent poor surface stability of the sand (McNitt and Landschoot, 2003; Sherratt et al., 2005). Recent studies completed by Bayrer (2006) and Williams et al. (2010) were conducted in the transition climatic zone and on native soil. Both studies reported significant differences in bermudagrass cultivars' response in tolerance to simulated athletic traffic. These studies also reported that in native soil conditions, the finer-textured, denser cultivars performed better under simulated athletic traffic.

The transition zone poses some challenges for growing bermudagrass. The dormancy period is one of the few disadvantages of using bermudagrass for sports turf applications in the northern regions. For this reason, overseeding is used as a tool to provide an actively growing, aesthetically pleasing turf that can withstand traffic (Horgan and Yelverton, 2001). Bermudagrass fields are often overseeded with perennial ryegrass to mask the dormant color. The ryegrass will provide a dense, green, aesthetically pleasing, and uniform playing surface while helping to reduce weed encroachment and thinning of the existing dormant bermudagrass turf from foot and equipment traffic (Horgan and Yelverton, 2001; Morris, 2004; Powell, 2005). Other viewpoints indicate that overseeding dormant bermudagrass is mainly just an aesthetic fix. Because the overseeding treatment is completed in the early fall, the perennial ryegrass turf remains as a weak seedling throughout the fall and may not contribute to increased wear tolerance or shear strength of the turf (Powell, 2006).

Plant growth regulators (PGRs) provide a means to control growth

Department of Plant and Soil Sciences, University of Kentucky, Room 310 Plant and Soil Science Building, Lexington, KY 40546-0312

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[1]Corresponding author. E-mail: mike.deaton@uky.edu.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
9.3540	gal/acre	$L \cdot ha^{-1}$	0.1069
2.54	inch(es)	cm	0.3937
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
6.8948	psi	kPa	0.1450

while actually improving general turfgrass quality. The gibberellic acid inhibitors, trinexapac-ethyl (TE) for this study, are the group of PGRs that have been shown to be the most feasible and essential for turf managers (Beasley and Branham, 2007; Fagerness and Yelverton, 2000). Reallocation of resources as a direct result of TE applications has been linked to faster recovery from heat, drought, and mechanical (divoting and ball marks on greens) stresses (McCann and Huang, 2007; Turgeon, 2005). A recently completed study by Williams et al. (2010) found that TE applied at label rates and frequencies generally produced a greater level of tolerance to simulated traffic than the untreated controls for several cultivars of bermudagrass grown in native soil.

Turf injury caused by direct pressure that crushes the leaves, stems, and crowns in concentrated traffic areas is termed turfgrass wear (Beard, 1973). Wear and compaction are the two major components that comprise turfgrass stresses from traffic (Beard, 1973; Trenholm et al., 2000; Turgeon, 2005). Traffic simulators for turf research have been designed and constructed in a variety of configurations. Cockerham and Brinkman (1989) developed the Brinkman traffic simulator (BTS) to perform traffic simulation from cleated-shoe traffic, which occurs as a result of wear, compaction, and lateral shear injury.

The objective of this study was to evaluate the effects of cultivars, applications of TE, and overseeding with perennial ryegrass on traffic tolerance of bermudagrass grown as football turf on a sand-based system. The significance of this study is that although all of these parameters (overseeding, bermudagrass cultivars, and TE) have been evaluated and published, no studies have been completed that evaluate these parameters together in sand-based systems. With the movement toward sand-based bermudagrass athletic fields, this study investigates several management parameters in an effort to define the best management practices for athletic field managers in the transitional climatic zone.

Materials and methods

The study site was constructed Fall 1997 and consisted of a 12-inch-deep, 9:1(v/v) sand-peat mix over a 4-inch layer of pea gravel with corrugated drain tile. Plots of 'Quickstand', 'Riviera', 'Tifway 419', and 'Yukon' bermudagrass were established Spring 2006 and maintained as athletic turf. Normal maintenance consisted of mowing daily at a height of 5/8 inch during peak growth and every other day in slower growth periods. Fertilizer applications were split into two biweekly applications of 21.4 lb/acre nitrogen (N) for a monthly total of 44 lb/acre N beginning in May and concluding in August of both years. This resulted in 175 lb/acre N applied annually in both years. Urea (46N–0P–0K) was used as the source of N. Irrigation was applied as needed to prevent any visible drought stress for the duration of the experiments. Applications to control crabgrass (*Digitaria* spp.) were made on 18 and 25 July 2007 and 25 July, 6 and 22 Aug. 2008. Monosodium methylarsonate (MSMA 6+©; Drexel Chemical, Memphis, TN) was applied at a rate of 2.04 lb/acre for each application.

The experimental design was a randomized block–split plot with a whole plot factor and a 3 × 2 subplot factorial structure with three replications. The experimental blocks were 7 × 36 ft and split plots or sampling units were 6 × 7 ft. The treatment factors for the experiment were the four cultivars (whole plot treatments), TE applied or

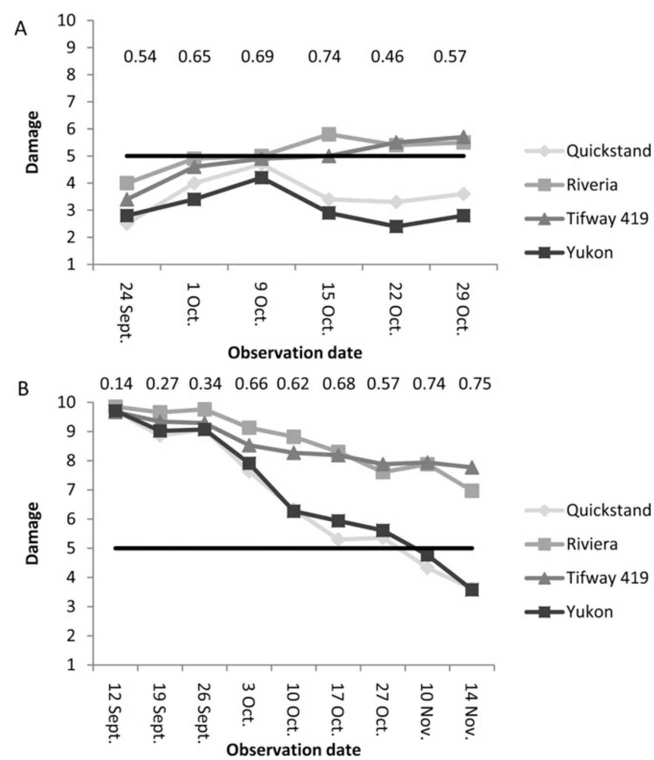

Fig. 1. Main effects of bermudagrass cultivars (Quickstand, Riviera, Tifway 419, and Yukon) on visual estimations of damage during applications of simulated athletic traffic equivalent to three games per week with the Brinkman traffic simulator in 2007 (A) and 2008 (B). Visual estimation of damage was recorded weekly and rated on a 1 to 10 scale, in which 1 represents bare soil and 10 represents 100% turfgrass cover. Visual estimations were made on bermudagrass cover before overseeding applications and bermudagrass/ryegrass cover after emergence of the ryegrass. All plots received nitrogen applied at 22 lb/acre (24.7 kg·ha^{-1}) every 2 weeks. Trinexapac-ethyl applications of 0.09 lb/acre (0.101 kg·ha^{-1}) were applied every 3 weeks throughout the 2007 and 2008 growing season. Perennial ryegrass overseeding treatments at the 546 lb/acre (612.0 kg·ha^{-1}) rate were applied 14 Sept.2007 and 28 Sept. 2008. Overseeding treatments at the 1093 lb/acre (1225.1 kg·ha^{-1}) rate were applied 21 Sept. 2007 and 7 Oct. 2008. Traffic treatments began 10 Sept. 2007 and 12 Sept. 2008 and continued through 2 Nov. 2007 and 14 Nov. 2008. Numbers above the curves indicate the least significant difference (LSD) value at $P < 0.05$ for each observation date. The horizontal line indicates the minimum acceptable damage level of five.

untreated, and no overseeding (OS) or OS at 546 or 1093 lb/acre rates [TE (2) × OS rates (3) subplot factorial treatments]. TE was applied at 3-week intervals throughout the bermudagrass growing season beginning 30 May and ending 5 Oct. 2007 and beginning 13 June and ending 15 Oct. 2008. Applications were made with a compressed carbon dioxide sprayer using four 8004 flat fan nozzles (Spraying Systems, Wheaton, IL) with a carrier rate (water) of 52 gal/acre at 30 psi. TE (Primo Maxx®; Syngenta, Wilmington, DE) was applied at a rate of 0.09 lb/acre. High-rate OS treatments were applied in split treatments in both years. All plots receiving medium and high rates were overseeded at the medium rate of 546 lb/acre pure live seed [PLS (% germination × % purity × 100)] on 14 Sept. 2007 and 28 Sept. 2008. The high-rate plots received the remaining 546 lb/acre PLS on 21 Sept. 2007 and 7 Oct. 2008 resulting in a total of 1093 lb/acre. Double Eagle Blend perennial ryegrass (Lesco-John Deer Landscapes, Troy, MI) was used for all OS treatments in both years. The blend consisted of 33.35% 'Prototype' perennial ryegrass, 32.07% 'Pacesetter' perennial ryegrass, and 31.75% 'Notable' perennial ryegrass. Ryegrass removal was accomplished by making three applications of foramsulfuron (Revolver©; Bayer Group, Leverkusen, Germany) at a rate of 0.027 lb/acre a.i. with a 4:1 (v/v) non-ionic surfactant on 21 Apr. and 7 and 23 May 2008. After ryegrass removal treatments, the bermudagrass was maintained as football field turf and allowed to recover from 23 May 2008 until traffic treatments resumed 12 Sept. 2008.

Traffic treatments were applied during the typical high school football season in Kentucky using the BTS three times per week, once each Monday, Wednesday, and Friday with no regard to soil moisture status or

Table 1. Results of analysis of variance for visual estimations of damage to bermudagrass on six observation dates[y] in 2007 and nine observation dates[y] in 2008 as affected by applications of 0.09 lb/acre (0.101 kg·ha^{-1}) trinexapac-ethyl (TE); perennial ryegrass overseeding (OS) treatments of 0, 546, and 1093 lb/acre (0.0, 612.0, and 1225.1 kg·ha^{-1}); and four bermudagrass cultivars (Quickstand, Riviera, Tifway 419, and Yukon) after initiation and during application of simulated traffic treatments with the Brinkman traffic simulator.[z]

	P > F Observation date 2007					
Source of variation	24 Sept.	1 Oct.	9 Oct.	15 Oct.	22 Oct	29 Oct.
Replication (R)	0.1295	0.0016	0.1557	0.5291	0.6834	0.3980
Cultivar (C)	<0.0001	0.0002	0.1321	<0.0001	<0.0001	<0.0001

Source of variation	*P* > F Observation date 2007					
	24 Sept.	1 Oct.	9 Oct.	15 Oct.	22 Oct.	29 Oct.
TE	0.1505	0.7188	0.1807	0.2478	1.0000	0.6797
OS	0.8614	0.0022	<0.0001	0.0550	<0.0001	<0.0001
C × TE	0.1322	0.2190	0.0501	0.1927	0.4655	0.3411
C × OS	0.0730	0.2153	0.2492	0.0012	0.0057	0.0030
TE × OS	0.8614	0.4419	0.7650	0.6176	0.1971	0.2223
C × TE × OS	0.3358	0.6396	0.5626	0.2559	0.1676	0.2271
CV (%)	11.84	16.93	19.61	19.40	11.64	15.20

Source of variation	*P* > F Observation date 2008						
	12 Sept.	19 Sept.	26 Sept.	3 Oct.	10 Oct.	17 Oct.	27 Oct.
R	0.0357	0.0028	0.6945	0.3009	0.0002	0.1460	0.0009
C	0.0821	<0.0001	0.0005	0.0002	<0.0001	<0.0001	<0.0001
TE	0.7837	0.2750	0.0299	0.0002	0.2509	0.6043	0.7315
OS	0.1826	0.1600	0.0862	0.4355	<0.0001	<0.0001	<0.0001
C × TE	0.2498	0.4698	0.0872	0.2232	0.8768	0.6389	0.2359
C × OS	0.0998	0.2285	0.0484	0.2415	0.0005	<0.0001	<0.0001
TE × OS	0.2034	0.6264	0.4936	0.4355	0.7893	0.9320	0.7079
CV (%)	2.19	4.39	5.54	11.96	12.55	14.65	12.89

	P > F Observation date 2008	
Source of variation	10 Nov.	14 Nov.
R	0.2338	0.6872
C	<0.0001	<0.0001
TE	0.5969	0.6784
OS	<0.0001	<0.0001
C × TE	0.7936	0.8166
C × OS	<0.0001	<0.0001
TE × OS	0.8855	0.8074
CV (%)	17.74	20.59

[z]Traffic treatments equivalent to three games per week began on 24 Sept. 2007 and 12 Sept. 2008 and continued until 29 Oct. 2007 and 14 Nov. 2008.
[y]Observations were collected approximately weekly after initiation of simulated traffic treatments.

weather for the periods 10 Sept. to 29 Oct. 2007 and 12 Sept. to 14 Nov. 2008. Traffic treatments consisted of making two passes in opposite directions over the same area covering the entire test site. This resulted in damage to the turf that is roughly equivalent to three football games per week. Visual estimation of damage was recorded weekly and rated on a 1 to 10 scale, in which 1 represents bare soil and 10 represents 100% turfgrass cover. Visual estimations were made on bermudagrass cover before overseeding applications and bermudagrass/ryegrass cover after emergence of the ryegrass. Data were analyzed using PROC GLM of SAS (Version 9.1; SAS Institute, Cary, NC). Means of damage were separated by F-protected least significant difference tests.

Results

The main effect of cultivar was significant ($P \leq 0.05$) on nearly every observation date for both 2007 and 2008 (Fig. 1; Table 1). Initiation of traffic treatments quickly produced differences in traffic tolerance among cultivars as shown in Figure 1. Significant differences were not always observed between the two denser, fine-leaved cultivars or between the two less dense, coarser cultivars. However, significant differences were consistently observed between these two groups of cultivars. ‘Riviera’ and ‘Tifway 419’ tolerated simulated traffic significantly better ($P < 0.05$) than ‘Quickstand’ and ‘Yukon’ in both 2007 and 2008. Differences between Figures 1A and 1B with respect to initial cover of bermudagrass are clearly evident. This difference is a direct result of a procedural error. The BTS had been set up for another traffic experiment and had not been reconfigured appropriately for this study. This resulted in excessive traffic being applied to the study site for the beginning of the 2007 data year. The study site was allowed to recover for as long as possible; however, the trial started with lower bermudagrass cover than the 2008 data year. However, significant differences among cultivars were still evident and recorded in 2007 (Fig. 1A).

The main effects of TE applications on turfgrass damage were not significant ($P > 0.05$) in 2007 or 2008 (Table 1). Turfgrass cover declined almost equally over the course of the application of traffic treatments in both years for TE-treated and untreated plots.

The main effects of overseeding were significant ($P \leq 0.05$) for 2007 and 2008 (Table 1). Ratings of damage were evaluations of bermudagrass only before OS and of the combination of bermudagrass and ryegrass after OS. Highly significant differences were recorded for all dates after establishment of the ryegrass except 1 and 15 Oct. in 2007 and for all dates after ryegrass establishment in 2008 (Fig. 2). Significant interactions were observed in turf damage with increasing OS rates in 2008 ($P < 0.001$) (Fig. 3) also in 2007 ($P < 0.05$) except to a lesser magnitude (Fig. 3). The greatest increases in traffic tolerance resulting from OS were observed in the more open, less dense cultivars Quickstand and Yukon (Fig. 3). The difference between the 2 years of the study may be directly related to the amount of irrigation the sites received. Irrigation differences between the 2 study years was the result of the irrigation requirement to establish a trial on a bordering site in 2008.

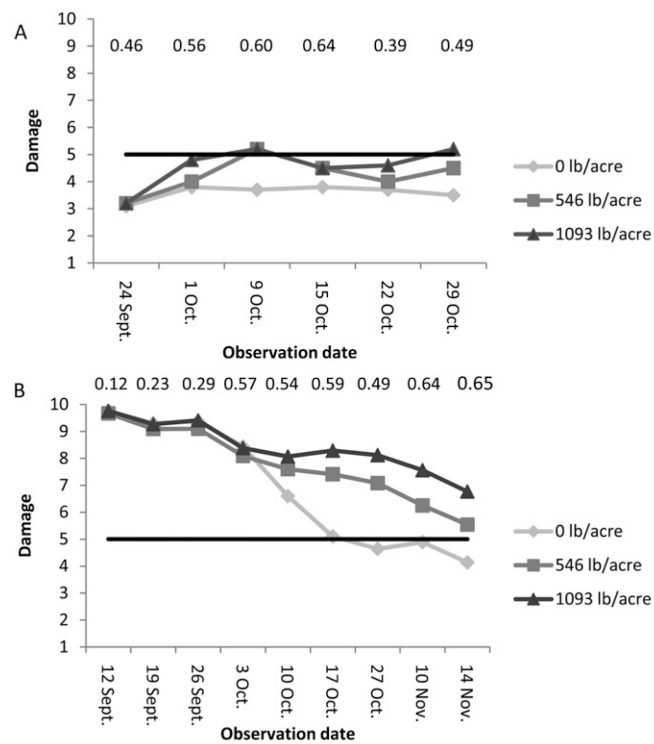

Fig. 2. The main effects of perennial ryegrass overseeding treatments on visual estimations of damage to bermudagrass during applications of simulated athletic traffic equivalent to three games per week with the Brinkman traffic simulator in 2007 (A) and 2008 (B). Visual estimation of damage was recorded weekly and rated on a 1 to 10 scale, in which 1 represents bare soil and 10 represents 100% turfgrass cover. Visual estimations were made on bermudagrass cover before overseeding applications and bermudagrass/ryegrass cover after emergence of the ryegrass. All plots received nitrogen applied at 22 lb/acre (24.7 $kg \cdot ha^{-1}$) every 2 weeks. Trinexapac-ethyl (TE) was applied at 0.09 lb/acre (0.101 $kg \cdot ha^{-1}$) every 3 weeks throughout the 2007 and 2008 growing seasons. Perennial ryegrass overseeding treatments at the 546 lb/acre (612.0 $kg \cdot ha^{-1}$) rate were applied 14 Sept. 2007 and 28 Sept. 2008. Overseeding treatments at the 1093 lb/acre (1225.1 $kg \cdot ha^{-1}$) rate were applied 21 Sept. 2007 and 7 Oct. 2008. Traffic treatments began 10 Sept. 2007 and 12 Sept. 2008 and continued through 2 Nov. 2007 and 14 Nov. 2008. Data are across four bermudagrass cultivars (Quickstand, Riviera, Tifway 419, and Yukon) and across TE applications of 0.09 lb/acre (0.101 $kg \cdot ha^{-1}$) applied every 3 weeks throughout the 2007 and 2008 growing seasons or no TE applications. Numbers above the curves indicate the least significant difference value at $P < 0.05$ for each observation date. The horizontal line indicates the minimum acceptable damage level of five.

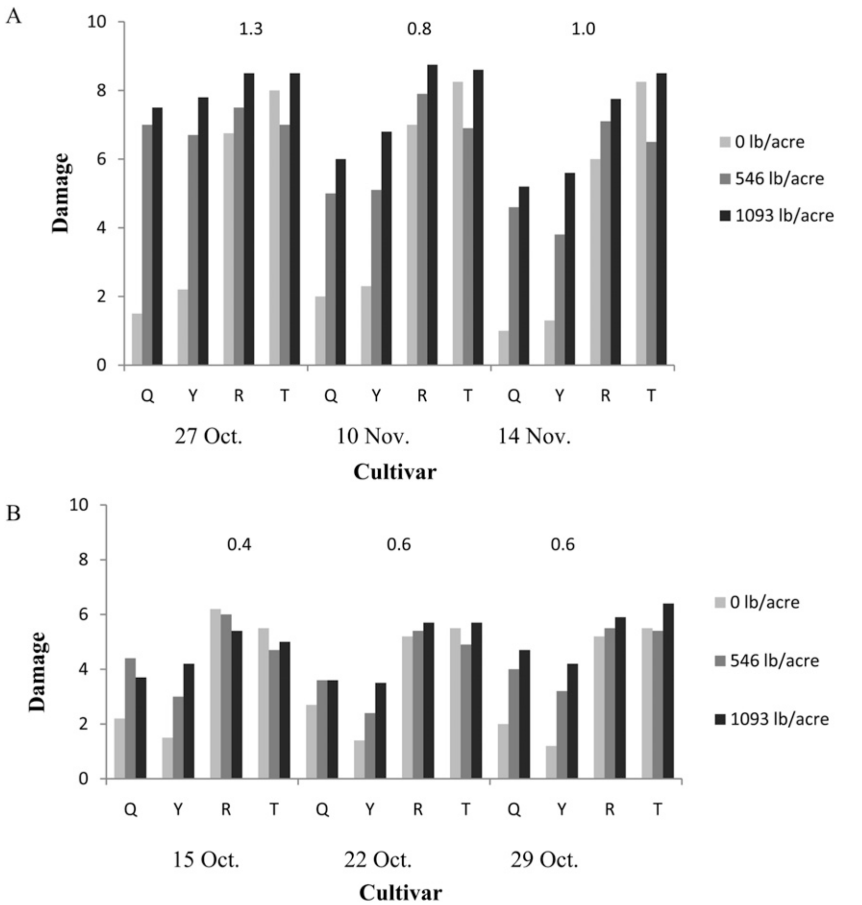

Fig. 3. Interaction of bermudagrass cultivars [Quickstand (Q), Riviera (R), Tifway 419 (T), and Yukon (Y)] and perennial ryegrass overseeding rates on visual estimations of damage on three observation dates during applications of simulated athletic traffic equivalent to three games per week with the Brinkman traffic simulator in 2007 (A) and 2008 (B). Visual estimation of damage was recorded weekly and rated on a 1 to 10 scale, in which 1 represents bare soil and 10 represents 100% turfgrass cover. Visual estimations were made on bermudagrass cover before overseeding applications and bermudagrass/ryegrass cover after emergence of the ryegrass. All plots received nitrogen applied at 22 lb/acre (24.7 kg·ha^{-1}) every 2 weeks. Perennial ryegrass overseeding treatments at the 546 lb/acre (612.0 kg·ha^{-1}) rate were applied 14 Sept. 2007 and 28 Sept. 2008. Overseeding treatments at the 1093 lb/acre (1225.1 kg·ha^{-1}) rate were applied 21 Sept. 2007 and 7 Oct. 2008. Traffic treatments began 10 Sept. 2007 and 12 Sept. 2008 and continued through 2 Nov. 2007 and 14 Nov. 2008. Data are across trinexapac-ethyl (TE) applications of 0.09 lb/acre (0.101 kg·ha^{-1}) applied every 3 weeks throughout the 2007 and 2008 growing seasons or no TE applications. Numbers above the bars indicate the least significant difference value at $P < 0.05$ for each observation date.

The extent of the decrease in damage may also be attributable to the ease of establishment of the ryegrass as a result of enhanced seed/soil contact of the less dense cultivars.

Discussion

In both years of the study, the main effects of cultivar in tolerance to simulated athletic traffic were significant ($P \leq 0.05$). This agrees well with earlier work (Bayrer, 2006; Williams et al., 2010) showing 'Riviera' tolerating simulated traffic significantly better than some other cultivars when grown in native soil. 'Riviera' and 'Tifway 419' were generally statistically equivalent and always outperformed the other cultivars in this work. 'Yukon', almost without exception, showed the poorest tolerance to simulated traffic in this study. This also agrees well with previous work (Bayrer, 2006). Cultivar selection for athletic turf grown on a sand-based system has been shown by this study to be significant and should be an important consideration before establishment of a new construction or renovation of an existing surface.

TE applications across both years of the study were shown not to be significant when evaluating tolerance to simulated traffic. This is in contrast to recent work (Williams et al., 2010) showing significant positive effects of TE applications when applied at label rates and frequencies on bermudagrass growing in native soil. Turfgrass damage over the course of this study was shown to increase with no significant difference between the plots that were or were not treated with TE. No consistent significant interactions were observed with TE and any other factor in this study.

OS treatments resulted in highly significant differences in turfgrass damage on most observations in both years of the study. The coarser textured, less dense cultivars Quickstand and Yukon were shown to respond much more positively to OS than the finer textured, denser cultivars. This is supported by the significant cultivar × OS interactions (Fig. 3; Table 1). 'Riviera' and 'Tifway 419' consistently showed less damage than the more open cultivars in this study regardless of OS or the lack thereof.

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