Effects of Various Plant Growth Regulators on the Traffic Tolerance of ‘Riviera’ Bermudagrass (*Cynodon dactylon* L.)

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Abstract. Data describing effects of plant growth regulator (PGR) applications on bermudagrass (*Cynodon* spp.) traffic tolerance are limited. A 2-year study was conducted evaluating effects of several PGRs on ‘Riviera’ bermudagrass (*Cynodon dactylon* L.) traffic tolerance. Treatments included 1) ethephon at 3.8 kg·ha⁻¹; 2) trinexapac-ethyl (TE) at 0.096 kg·ha⁻¹; 3) paclobutrazol at 0.28 kg·ha⁻¹; 4) flurprimidol at 0.0014 kg·ha⁻¹; 5) flurprimidol + TE at 0.0014 kg·ha⁻¹ + 0.096 kg·ha⁻¹, respectively; 6) ethephon + TE at 3.8 kg·ha⁻¹ + 0.096 kg·ha⁻¹, respectively; and 7) untreated control. All treatments were applied three times on a 21-d interval before trafficking. Plots were subjected to three simulated football games per week with the Cady Traffic Simulator. Traffic began 2 weeks after the last sequential application of each PGR. Turfgrass color, quality, and cover were quantified weekly using digital image analysis. Turfgrass cover measurements were used to assess traffic tolerance. Improvements in turfgrass color, quality, and cover were observed with applications of TE, ethephon + TE, and flurprimidol + TE. Turfgrass color, quality, and cover were enhanced for ethephon + TE and flurprimidol + TE compared with applications of ethephon and flurprimidol alone. Considering that no differences in turfgrass color, quality, or cover were detected among TE, ethephon + TE, and flurprimidol + TE at any time in the study, the responses observed suggest that TE may have a greater impact than other PGRs on ‘Riviera’ bermudagrass athletic field turf when applied before traffic stress. Chemical names used: rthephon (2-chloroethyl)-phosphonic acid; glurprimidol {α-(1-methylethyl)-α-[4-(trifluoro-methoxy) phenyl] 5-pyrimidine-methanol}; paclobutrazol, (+/-)-(R*,R*)-β-[(4-chlorophenyl) methyl]-α-(1-1-dimethyl)-1H-1,2,4-triazole-1-ethanol; trinexapac-ethyl [4-(cyclopropyl-α]-hydroxymethylene)-3,5-dioxo-cyclohexane carboxylic acid ethyl ester].

Bermudagrasses (*Cynodon* spp.) are commonly used on athletic fields in the U.S. transition zone, because they offer increased recuperative potential and heat tolerance compared with other turfgrass species (Christians, 2004). Traffic is the most frequent and damaging stress imposed to bermudagrass athletic fields, because it induces two forms of damage: wear and soil compaction (Carrow and Petrovic, 1992; Minner et al., 1993). Wear is characterized by injury (tearing) of leaf tissues, whereas soil compaction negatively alters soil physical properties (Carrow and Petrovic, 1992).

Plant growth regulators (PGRs) have been defined as organic compounds that alter turfgrass growth or development by targeting the actions of plant hormones (DiPaola, 1988). Gibberellins, auxins, cytokinins, and ethylene are examples of naturally occurring plant hormones that affect growth (Arteca, 1996). Applications of PGRs can affect turf

growth and development by inhibiting or stimulating hormonal action (Serensits, 2008).

Trinexapac-ethyl (TE), a Class A PGR, acts late in the gibberellin biosynthesis pathway by inhibiting the conversion of GA₂₀ to GA₁, reducing cell elongation and in turn vertical growth (Adams et al., 1992). Although applications of TE at rates of 0.1 kg·ha⁻¹ or less have been shown to suppress growth and increase the turf quality of several bermudagrasses (Baldwin et al., 2009; Fagerness and Yelverton, 2000; McCullough et al., 2005a, 2005b, 2006), certain physiological responses have also been observed after treatment with TE that may improve turfgrass traffic tolerance. Waltz and Whitwell (2005) reported that TE increased the non-structural carbohydrate content (TNC) of hybrid bermudagrass (*C. dactylon* × *C. transvaalensis* Burt-Davey) root and shoot tissues. Increased TNC may improve traffic tolerance in that TNC can be used as an energy reservoir to promote stress tolerance and regrowth after leaf tissue removal (Huang and Jiang, 2002). TE has also been reported to increase the content of structural carbohydrates in cell walls (Heckman et al., 2005),

which has been associated with improved wear tolerance in several cool- and warm-season turfgrass species (Brosnan et al., 2005; Hoffman et al., 2010; Trenholm et al., 2000).

Applications of TE have been shown to increase tiller density (Beasley et al., 2005; Ervin and Koski, 1998), which has been associated with improved traffic tolerance (Trenholm et al., 2000). Ervin and Zhang (2007) suggested that elevated cytokinin content in hybrid bermudagrass crowns after treatment with TE may lead to increased cell division and consequently increased tiller density. However, the influence of TE on tiller density in the field has been erratic (Ervin and Koski, 2001; Lickfeldt et al., 2001; Stier and Rogers, 2001). Serensits (2008) reported that sequential applications of TE at 0.17 kg·ha⁻¹ before traffic stress increased the tiller density of several kentucky bluegrass (*Poa pratensis* L.) cultivars established on a sand-based root zone but did not affect traffic tolerance.

Paclobutrazol and flurprimidol are Class B PGRs that act early in the gibberellin biosynthesis pathway by preventing the conversion of *ent*-kaurene to *ent*-kaurenoic acid (Buchanan et al., 2000; Sponsel, 1995). Both of these PGRs are absorbed primarily by turfgrass roots (Anonymous, 2009; Tukey, 1986), whereas TE absorption occurs primarily through the foliage (Fagerness and Penner, 1998). Applications of flurprimidol and paclobutrazol have been shown to suppress both common and hybrid bermudagrass growth, but significant injury has also been observed after application (Johnson, 1989, 1990a, 1990b, 1992, 1994; McCullough et al., 2005c, 2005d). Applications of flurprimidol and paclobutrazol may negatively affect bermudagrass traffic tolerance, as McCullough et al. (2005c, 2005d) observed reductions in shoot density, root mass, and root length after application. These morphological changes would likely render bermudagrass less tolerant of traffic stress; however, data describing the effects of flurprimidol and paclobutrazol on bermudagrass traffic tolerance have not been reported.

Ethephon, a Class E PGR that affects plant growth by releasing the hormone ethylene, is mainly used to suppress seed head formation (Serensits, 2008). McCullough et al. (2005b) reported a 22% reduction in growth (measured as clipping reduction) with sequential ethephon applications to ‘TifEagle’ hybrid bermudagrass; however, the researchers also reported linear reductions in bermudagrass quality with increasing rates of ethephon and as high as a 33% reduction in root mass. Although shoot density was not measured, both McCullough et al. (2005b) and Shatters et al. (1998) observed discolorations in bermudagrass leaf tissue and severe shoot thinning after treatment with ethephon. These responses suggest that ethephon may reduce bermudagrass traffic tolerance, but data describing the effects of ethephon on bermudagrass athletic field turf have not been reported.

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Mixtures of TE with ethephon and flurprimidol have been shown to mitigate the negative effects that have been reported after treatment with flurprimidol and ethephon alone. McCullough et al. (2005b) reported that mixtures of ethephon + TE yielded increased bermudagrass quality, root length, and root mass values compared with ethephon alone. Kane and Miller (2003) reported that mixtures of ethephon + TE reduced the level of creeping bentgrass (*Agrostis stolonifera* L.) discoloration that had been observed with applications of ethephon alone. Totten et al. (2006) did not report improvements in clipping reduction or lateral regrowth for mixtures of flurprimidol + TE compared with TE or flurprimidol applied alone, but note that their findings do not rule out the potential benefits of applying flurprimidol + TE. Data describing the traffic tolerance of bermudagrass treated with mixtures of ethephon + TE and flurprimidol + TE have not been reported.

Although applications of PGRs have been shown to improve bermudagrass quality and alter plant morphology, data on bermudagrass traffic tolerance after treatment with various PGRs are limited. The objective of this study was to evaluate the traffic tolerance of 'Riviera' bermudagrass (*Cynodon dactylon* L.) after treatment with various PGRs commercially marketed for use in turfgrass management.

Materials and Methods

Research site. A 2-year field study was conducted in 2008 and 2009 on a stand of 'Riviera' bermudagrass at the University of Tennessee (Knoxville, TN). Turf had been established on a Sequatchie loam soil (fine-loamy, siliceous, semiactive, thermic humic Hapludult), measuring 6.2 in soil pH and 2.1% in organic matter content 4 years before initiating this study. Irrigation was applied to prevent wilt and turf was mowed weekly at a 16-mm height with clippings returned.

Treatments evaluated. The experimental design was a randomized complete block with three replications. Treatments included 1) ethephon at 3.8 kg·ha⁻¹; 2) TE at 0.096 kg·ha⁻¹; 3) paclobutrazol at 0.28 kg·ha⁻¹; 4) flurprimidol at 0.0014 kg·ha⁻¹; 5) flurprimidol + TE at 0.0014 kg·ha⁻¹ + 0.096 kg·ha⁻¹, respectively; 6) ethephon + TE at 3.8 kg·ha⁻¹ + 0.096 kg·ha⁻¹, respectively; and 7) untreated control. All treatments were applied with a CO₂-powered boom sprayer equipped with four 8002 flat-fan nozzles (Tee Jet; Spraying Systems Co., Roswell, GA) calibrated to deliver 281 L·ha⁻¹ of spray volume. All treatments were applied three times on a 21-d interval beginning on 22 July 2008 and 1 July 2009. Plot size measured 1.5 × 3.0 m.

A Cady Traffic Simulator (CTS), developed according to the methods of Henderson et al. (2005), was used to apply simulated

traffic to plots beginning 2 weeks after the last sequential PGR application. The CTS is a modified, walk-behind, core-cultivation unit (Vaerator VA-24; Jacobsen, A Textron Co., Charlotte, NC) fitted with fabricated "feet" that are attached to the core heads instead of coring tines. These feet alternately strike the turfgrass surface as the machine moves to simulate the dynamic forces characteristic of traffic stress. The CTS creates a traffic pass 2.2 m wide and generates 667 cleat marks/m² (Goddard et al., 2008). Two passes with the CTS produces the same number of cleat marks/m² that would be found after one National Football League (NFL) game between the hashmarks at the 40-yard line (Henderson et al., 2005). Vanini et al. (2007) reported that the CTS produces more intense traffic than the Brinkman Traffic Simulator developed by Cockerham and Brinkman (1989) as a result of differences in cleat surface area between the two devices (Henderson et al., 2005). In this study, plots were subjected to six passes with the CTS per week to simulate the effects of three weekly NFL games. Simulated traffic initiated on 19 Sept. 2008 and 27 Aug. 2009, 2 weeks after the last sequential application of each PGR treatment.

Data collected. Traffic tolerance was quantified by measuring turfgrass cover after each traffic event using digital image analysis (DIA). DIA has been shown to provide

Table 1. Turfgrass color values for 'Riviera' bermudagrass (*Cynodon dactylon*) treated with various plant growth regulators before initiating simulated traffic in 2008 and 2009.

Treatment	Rate (kg·ha ⁻¹)	2008 Turfgrass color (1 to 9) ^a Simulated traffic events					
		3	6	9	12	15	18
Untreated control	—	5.1	5.3	5.2	5.8	5.5	5.5
Ethephon	3.8	3.8	3.8	4.0	4.8	6.0	4.8
Trinexapac-ethyl (TE)	0.096	8.2	7.8	8.0	8.3	5.3	4.5
Paclobutrazol	0.28	5.0	6.0	5.7	4.7	3.8	3.3
Flurprimidol	0.0014	4.2	4.8	4.3	4.2	3.5	3.3
Flurprimidol + TE	0.0014 + 0.0526	7.5	8.8	7.8	8.0	5.5	4.0
Ethephon + TE	3.8 + 0.0526	8.3	7.7	7.5	7.7	5.0	4.5
LSD _{0.05}		0.9	1.5	1.9	2.7	NS	NS
TE versus flurprimidol + TE		NS ^y	NS	NS	NS	NS	NS
TE versus ethephon + TE		NS	NS	NS	NS	NS	NS
Flurprimidol versus flurprimidol + TE		***x	***	**	**	NS	NS
Ethephon versus ethephon + TE		***	***	**	*	NS	NS
Treatment	Rate (kg·ha ⁻¹)	2009 Turfgrass color (1 to 9) Simulated traffic events					
		3	6	9	12	15	18
Untreated control	—	5.7	5.8	7.3	5.7	7.0	7.5
Ethephon	3.8	5.5	5.7	7.2	6.0	6.3	6.8
Trinexapac-ethyl (TE)	0.096	7.0	6.8	8.0	7.5	7.7	7.7
Paclobutrazol	0.28	4.5	5.2	6.3	5.5	5.8	6.5
Flurprimidol	0.0014	5.0	4.8	5.5	5.5	6.0	6.8
Flurprimidol + TE	0.0014 + 0.0526	5.0	7.0	7.7	6.0	6.5	7.5
Ethephon + TE	3.8 + 0.0526	7.7	7.3	8.0	7.5	8.5	8.3
LSD _{0.05}		NS	NS	1.5	1.5	1.3	1.2
TE versus flurprimidol + TE		NS	NS	NS	NS	NS	NS
TE versus ethephon + TE		NS	NS	NS	NS	NS	NS
Flurprimidol versus flurprimidol + TE		***	***	**	**	*	NS
Ethephon versus ethephon + TE		***	***	**	*	NS	NS

^aTurfgrass color values were on a scale of 1 to 9, with 1 being brown, 9 being dark green, and 6 being minimum acceptable color based on digital image analysis.

^yNS = nonsignificant at the $P \leq 0.05$ level.

x*, **, ***Significant at the $P \leq 0.05$, 0.01, and 0.001 levels, respectively.

LSD = least significant difference.

quantitative measurements of turfgrass performance while removing observational bias (Karcher, 2007; Karcher and Richardson, 2003; Richardson et al., 2001). Turfgrass color and quality were also measured after each traffic event using DIA.

DIA quantifies turfgrass cover, color, and quality by scanning pixels. Before initiating simulated traffic, a location was randomly selected on each plot for digital imaging. To monitor changes over time, the same area was selected for DIA for the duration of the study. Digital images were captured using a 0.28-m² light box equipped with four TCP 40-W Spring Lamps[®] (Lighthouse Supply Co., Bristol, VA) and powered by a Xantrex 600 HD Power Pack[®] (Xantrex Technology, Vancouver, British Columbia, Canada). Digital images were taken with a Canon G5 (Canon Inc., Japan) camera capable of capturing 5 million pixels per image. Total image size in this study was 307,200 pixels.

SigmaScan Pro software (Version 5.0; SPSS Inc., Chicago, IL) was used to express image pixelation as measurements of turfgrass cover and color according to the methods of Richardson et al. (2001) and Karcher and Richardson (2003). Pixelation was also used to determine turfgrass quality (D. Karcher, personal communication). Pixels defined as green turf exhibited a hue range of 45° to 120° and saturation values

between 0% and 100%. To calculate turfgrass cover, the number of green turf pixels in each image was divided by the total number of pixels in the image (307,200 pixels). Pixels defined as green turf were also used to calculate turfgrass color and quality on a 1 to 9 scale, in which 1 = brown, low-quality turf and 9 = dark green, high-quality turf. A score greater than or equal to six was considered acceptable for both turfgrass color and quality.

Statistical analysis. Data were subjected to analysis of variance using SAS (SAS Institute Inc., Cary, NC). Fisher's protected least significant difference values are reported for comparisons at the $\alpha = 0.05$ level. Significant year-by-treatment interactions were detected; thus, data from each year were analyzed and are presented individually. In addition, between-group comparisons using pairwise contrasts ($\alpha = 0.05$) were used to evaluate preplanned comparisons imbedded within the treatment structure.

Results and Discussion

Turfgrass color. Turfgrass color values varied as a result of treatment on four of six rating dates in 2008. Color values for plots treated with TE were greater than the untreated control on all but one date that treatment differences were detected. A similar

relationship was observed for mixtures of flurprimidol + TE and ethephon + TE (Table 1). Turfgrass color values for flurprimidol and ethephon were not significantly different from the untreated control on the majority of rating dates; however, on each date that color values varied as a result of treatment, mixtures of flurprimidol + TE and ethephon + TE yielded increased color values compared with flurprimidol and ethephon applied alone. Similarly, treatment with TE alone enhanced color compared with ethephon, paclobutrazol, and flurprimidol. There were no differences in turf color detected among TE, flurprimidol + TE, and ethephon + TE on any rating date (Table 1).

In 2009, turfgrass color values for TE-treated plots only exceeded the untreated control on a single rating date (12 simulated traffic events; Table 1). Turfgrass color values for mixtures of flurprimidol + TE were not different from the untreated control on any rating date, whereas those for ethephon + TE-treated plots exceeded the untreated control on two rating dates (Table 1). Similarly, turfgrass color values for flurprimidol + TE and ethephon + TE were greater than those measured on plots treated with flurprimidol and ethephon applied alone. Additionally, differences in turf color were not detected among TE, flurprimidol + TE, and ethephon + TE on any rating date (Table 1).

Table 2. Turfgrass quality values for 'Riviera' bermudagrass (*Cynodon dactylon*) treated with various plant growth regulators before initiating simulated traffic in 2008 and 2009.

Treatment	Rate (kg-ha ⁻¹)	2008					
		Turfgrass quality (1 to 9)					
		Simulated traffic events					
		3	6	9	12	15	18
Untreated control	—	7.0	7.0	6.8	7.2	6.7	6.7
Ethephon	3.8	5.8	5.8	5.7	6.2	6.8	6.3
Trinexapac-ethyl (TE)	0.096	8.8	8.0	8.2	8.5	7.5	6.8
Paclobutrazol	0.28	7.3	7.0	6.8	6.5	6.0	5.7
Flurprimidol	0.0014	5.8	6.5	6.0	6.2	5.5	5.5
Flurprimidol + TE	0.0014 + 0.0526	8.3	8.7	8.2	8.5	7.7	7.2
Ethephon + TE	3.8 + 0.0526	8.3	7.7	7.7	8.0	7.0	6.8
LSD _{0.05}		0.9	1.3	1.6	1.7	NS	NS
TE versus flurprimidol + TE		NS ²	NS	NS	NS	NS	NS
TE versus ethephon + TE		NS	NS	NS	NS	NS	NS
Flurprimidol versus flurprimidol + TE		****	**	*	*	*	NS
Ethephon versus ethephon + TE		***	*	*	*	NS	NS

Treatment	Rate (kg-ha ⁻¹)	2009					
		Turfgrass quality (1 to 9)					
		Simulated traffic events					
		3	6	9	12	15	18
Untreated control	—	6.7	6.7	7.8	6.8	7.0	7.3
Ethephon	3.8	6.7	6.8	7.8	7.3	6.8	7.2
Trinexapac-ethyl (TE)	0.096	7.3	7.2	8.3	8.3	7.5	8.2
Paclobutrazol	0.28	6.2	7.5	7.3	6.8	6.7	7.3
Flurprimidol	0.0014	6.5	6.3	6.7	7.0	6.7	7.3
Flurprimidol + TE	0.0014 + 0.0526	7.5	7.5	8.0	7.3	6.8	7.7
Ethephon + TE	3.8 + 0.0526	7.5	7.3	8.3	8.0	8.0	8.5
LSD _{0.05}		NS	NS	NS	NS	0.7	NS
TE versus flurprimidol + TE		NS	NS	NS	NS	NS	NS
TE versus ethephon + TE		NS	NS	NS	NS	NS	NS
Flurprimidol versus flurprimidol + TE		***	**	*	*	*	NS
Ethephon versus ethephon + TE		***	*	*	*	NS	NS

²Turfgrass quality values were on a scale of 1 to 9, with 1 being low-quality turf, 9 being high quality, and 6 being minimum acceptable quality based on digital image analysis.

³NS = nonsignificant at the $P \leq 0.05$ level.

*, **, ***Significant at the $P \leq 0.05$, 0.01, and 0.001 levels, respectively.

LSD = least significant difference.

Turfgrass quality. Turfgrass quality varied from treatments on four of six rating dates in 2008. Plots treated with TE and ethephon + TE only measured higher in quality than the untreated control after three simulated traffic events (Table 2). Turfgrass quality values for TE exceeded those measured for flurprimidol and ethephon on each date that significant treatment differences were detected; however, no differences were detected among TE, flurprimidol + TE, and ethephon + TE on any rating date (Table 2). In 2009, quality values only varied as a result of treatment on a single rating date (15 simulated traffic events) and values for TE-treated plots were not significantly different from the untreated control (Table 2). TE-induced increases in turfgrass quality were less pronounced than those reported by other researchers (Baldwin et al., 2009; Fagerness and Yelverton, 2000; McCullough et al., 2005a, 2005b, 2006). This was likely because turf in this study was subjected to simulated traffic stress, whereas other data describing TE effects on turfgrass quality have been collected on non-trafficked turf. Additionally, the majority of turfgrass quality data were collected when turf was likely not under TE-induced growth regulation, because data collection began 2 weeks after the last sequential TE application. Other researchers investigating the effects of TE on bermudagrass (Baldwin et al., 2009; Fager-

ness and Yelverton, 2000; McCullough et al., 2005a, 2005b, 2006) have evaluated turf that was continually under TE-induced growth regulation.

Similar to what was observed in turfgrass color data, quality values for flurprimidol + TE and ethephon + TE exceeded those measured for flurprimidol and ethephon applied alone in both 2008 and 2009 (Table 2). These data are similar to those reported by McCullough et al. (2005b) who observed increases in bermudagrass turf quality with mixtures of ethephon + TE compared with ethephon alone. Turfgrass quality was not measured by Totten et al. (2006); however, the researchers noted little benefit in applying flurprimidol + TE compared with either PGR alone.

Turfgrass cover. Turfgrass cover values for plots treated with TE at 0.096 kg·ha⁻¹ were greater than the untreated control on four of six rating dates in 2008 (Table 3). These results differ from those reported by Marshall (2007) who found TE reduced bermudagrass traffic tolerance; however, in the work of Marshall (2007), TE was applied in conjunction with the implementation of simulated traffic. In this study, simulated traffic was initiated 14 d after the last TE application.

Although no differences were detected among TE, ethephon + TE, and flurprimidol + TE on any rating date, turfgrass cover values for ethephon + TE and flurprimidol

+ TE exceed those measured on plots treated with ethephon and flurprimidol alone (Table 3). Paclobutrazol and flurprimidol did not yield lower turfgrass cover values than the untreated control in 2008. This response indicates that the deleterious effects reported by other researchers (Johnson, 1989, 1990a, 1990b, 1992, 1994; McCullough et al., 2005c, 2005d) after applications of these PGRs may not affect 'Riviera' bermudagrass traffic tolerance.

Although similar trends were apparent in 2009, turfgrass cover values did not vary as a result of treatment on any rating date. Reasons for the lack of differences in 2009 are not clear. The 'Riviera' bermudagrass stand on which this study was conducted was vertically mowed and core-aerated 4 months before treatment application in 2009. This event marked the first time this turf stand had been vertically mowed and aerated since it had been established. These cultural practices may have improved bermudagrass traffic tolerance, because values for the untreated control were significantly greater in 2009 compared with 2008. For example, after 12 simulated games, turfgrass cover for the untreated control measured 42% in 2008 compared with 63% in 2009. At the conclusion of the trial in 2008, turfgrass cover for the untreated control measured 10% in 2008 compared with 39% in 2009.

Table 3. Turfgrass cover values for 'Riviera' bermudagrass (*Cynodon dactylon*) treated with various plant growth regulators before initiating simulated traffic in 2008 and 2009.

Treatment	Rate (kg·ha ⁻¹)	2008					
		Turfgrass cover (%)					
		Simulated traffic events					
		3	6	9	12	15	18
Untreated control	—	86	65	63	42	13	10
Ethephon	3.8	76	53	53	40	13	11
Trinexapac-ethyl (TE)	0.096	95	71	70	64	27	20
Paclobutrazol	0.28	92	70	70	52	19	15
Flurprimidol	0.0014	80	64	61	45	17	14
Flurprimidol + TE	0.0014 + 0.0526	94	79	76	67	31	24
Ethephon + TE	3.8 + 0.0526	94	73	72	59	25	20
LSD _{0.05}		6	11	10	11	6	5
TE versus flurprimidol + TE		NS ²	NS	NS	NS	NS	NS
TE versus ethephon + TE		NS	NS	NS	NS	NS	NS
Flurprimidol versus flurprimidol + TE		***y	**	**	***	***	***
Ethephon versus ethephon + TE		***	***	**	**	**	**
Treatment	Rate (kg·ha ⁻¹)	2009					
		Turfgrass cover (%)					
		Simulated traffic events					
		3	6	9	12	15	18
Untreated control	—	82	77	73	63	43	39
Ethephon	3.8	82	76	73	66	42	36
Trinexapac-ethyl (TE)	0.096	92	82	81	79	61	51
Paclobutrazol	0.28	73	75	71	63	45	40
Flurprimidol	0.0014	79	73	67	64	45	44
Flurprimidol + TE	0.0014 + 0.0526	89	83	78	66	45	44
Ethephon + TE	3.8 + 0.0526	91	84	82	80	67	56
LSD _{0.05}		NS	NS	NS	NS	NS	NS
TE versus flurprimidol + TE		NS	NS	NS	NS	NS	NS
TE versus ethephon + TE		NS	NS	NS	NS	NS	NS
Flurprimidol versus flurprimidol + TE		***	*	**	***	***	***
Ethephon versus ethephon + TE		***	**	**	**	**	**

²Turfgrass cover values were on a percent scale from 0 to 100 using digital image analysis.

^yNS = nonsignificant at the $P \leq 0.05$ level.

*, **, ***Significant at the $P \leq 0.05$, 0.01, and 0.001 levels, respectively.

LSD = least significant difference.

Conclusion

These results suggest that TE may be better suited than other PGRs for use on 'Riviera' bermudagrass athletic fields before the initiation of traffic stress. Although TE-induced improvements in turfgrass color, quality, and cover were observed, the inclusion of TE in mixtures with ethephon and flurprimidol also increased 'Riviera' bermudagrass color, quality, and cover compared with applications of ethephon and flurprimidol alone. Considering that no differences in turfgrass color, quality, or cover were detected among TE, ethephon + TE, and flurprimidol + TE at any time in the study, the responses observed suggest that TE may have a greater impact than other PGRs on 'Riviera' bermudagrass athletic field turf when applied before traffic stress. Additional research is needed to evaluate the effects of TE on other bermudagrasses selected for use on athletic fields.

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