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Effects of Trinexapac-Ethyl on the Salinity Tolerance of Two Ultradwarf Bermudagrass Cultivars

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Abstract*. Studies on bermudagrasses (*Cynodon* spp.) have demonstrated variability in salinity response among species and cultivars. However, information on ultradwarf bermudagrass cultivars in relative salinity tolerance associated with trinexapac-ethyl (TE) [4-(cyclopropyl-α-hydroxy-methylene)-3,5-dioxocyclohexanecarboxylic acid ethyl ester], a cyclohexanedione type II plant growth regulator (PGR), remains unknown. Therefore, two replicated greenhouse studies were conducted to determine the salinity tolerance of two ultradwarf bermudagrass cultivars treated with TE on turfgrass quality (TQ), total root biomass, and root and shoot tissue nutrient concentration. Turfgrasses included 'TifEagle' and 'Champion' bermudagrass (*Cynodon dactylon* (L.) Pers. × *C. transvaalensis* Burtt-Davy). Daily sodium chloride (NaCl) exposure was 0, 12.90 (8,000 ppm), 25.80 (16,000 ppm), and 38.71 dS·m^{-1} (24,000 ppm). Biweekly TE applications (active ingredient 0.02 kg·ha^{-1}) were initiated 2 weeks after salinity exposure. 'Champion' was more salt-tolerant than 'TifEagle' based on TQ and root mass. At 12.90, 25.80, and 38.71 dS·m^{-1} of NaCl, nontreated (without TE) 'Champion' consistently outperformed nontreated 'TifEagle' with greater TQ on most rating dates. At 12.90 dS·m^{-1}, TE treated 'Champion' (8.0) had greater TQ than nontreated 'TifEagle' (6.1) at week 10. Regardless of TE application, after 2 weeks of applying 25.80 dS·m^{-1} of NaCl, both cultivars fell below acceptable TQ (<7). When averaged across all salinity treatments, applying TE four times at 0.02 kg·a.i./ha in two week intervals enhanced root growth for both bermudagrass cultivars by 25%. Also, both cultivars decreased root mass as salinity levels increased. Non TE-treated 'TifEagle' had 56% and 40% less root and shoot Na uptake compared to TE treated cultivars at 25.80 dS·m^{-1}. In conclusion, the two bermudagrass cultivars responded differently when exposed to moderate levels of NaCl.

Global demand for fresh potable water doubles every 20 years, therefore, turfgrass managers continuously seek alternative water sources (Duncan and Carrow, 2000). Salt water exposure often weakens turfgrasses and reduces growth to a point of unacceptable quality. Current cultural practices to relieve salinity stress include planting salt-tolerant grasses, leaching excess salts, modifying soils with various amendments to replace or leach Na and Cl from the soil, and enhancing soil drainage with subsurface drainage (McCarty, 2005).

Two major causes of plant growth inhibition under salinity stress are osmotic stress (osmotic inhibition of plant water absorption) and specific ion effects (Marcum, 2002). Generally, plants absorb water and nutrients by osmosis. As salts enter the soil profile, water uptake is inhibited as the osmotic gradient changes (Harivandi et al., 1992). At lower salt concentrations, an osmotic adjustment may allow the plant to continue water uptake, maintain cell turgor, cell expansion, and other metabolic activities (Carrow and Duncan, 1998). When salt levels are extremely high, the osmotic potential may reverse water flow from plant cells into soil solution, causing plant cells to collapse and desiccate (Harivandi et al., 1992; Marcum, 1999).

Plants have developed several mechanisms to tolerate salinity stress. Salt exclusion is one major physiological process associated with salt tolerance (Marcum, 2002). As salt loads increase, salt-sensitive (glycophytes) species have developed a mechanism of removing Na from the xylem sap into the phloem, which leads to high salt transport out of shoot tissue (Carrow and Duncan, 1998). Meanwhile, some salt-tolerant (halophytes) species excrete salts through microscopic two-celled salt glands which lie flat on the leaf surface, in rows parallel to stomates (Marcum et al., 2003). Salt glands have been found in many warm-season turfgrasses including bermudagrass (*Cynodon* spp.). Marcum et al. (2003) demonstrated that as salt gland density increased, salt tolerance of zoysiagrass (*Zoysia* spp.) also increased. Other species are capable of translocating salts to lower leaves and then discarding salts or reducing salt uptake by developing a thicker root casparian strip (Carrow and Duncan, 1998).

Many studies have been conducted to determine the salinity tolerance of warm-season turfgrasses (Ackerson and Youngner, 1975; Dudeck et al., 1983; Dudeck and Peacock, 1993; Marcum et al., 1998; Qian et al., 2000). However, the salinity tolerance of two popular ultradwarf hybrid bermudagrass cultivars used on golf course putting greens, 'TifEagle' and 'Champion', is unknown.

Trinexapac-ethyl is a foliar absorbed cyclohexanedione Type II gibberellic acid (GA) inhibiting PGR (Fagerness and Penner, 1998) which effectively reduces leaf elongation. Trinexapac-ethyl inhibits cell elongation late in the mevalonic acid pathway by stopping the conversion GA_{20} to GA_1 (Fagerness and Penner, 1998). Typical turfgrass responses to TE may include a darker green color, increased shoot density, and smaller, more compact leaves.

The primary absorption site for TE is the leaf sheaths surrounding the compressed stem and the plant crown, while roots absorb only 5% after 24 h (Fagerness and Penner, 1998). Therefore, any inhibition of root growth when applying TE is correlated to the effects of reduced shoot growth. In a nitrogen use study, Fagerness et al. (2004) stated TE application does not increase nitrate leaching in 'Tifway' bermudagrass, but increases fertility recovery when the active ingredient is applied twice at 0.11 kg·ha^{-1} in 4-week intervals.

Until the release of TE, PGR use on high-quality turf was limited due to potential phytotoxic effects on warm and cool-season turfgrasses (Shepard, 2002). Undesirable characteristics included phytotoxicity of treated leaves, reduced recuperative ability, and increased weed pressure due to reduced competition from treated turfgrasses (McCarty, 2005). Initially, TE was developed to reduce mowing frequency, however, recent studies have investigated TE's influence on improving water use efficiency, heat tolerance, and shade tolerance (Bunnell et al., 2005; Steinke and Stier, 2003; Zhang et al., 2003). Trinexapac-ethyl provides a more compact, smaller leaf blade (reducing transpiration) and a more dense turf (reducing soil evaporation). Applying TE to a salt-stressed turf may enhance quality by reducing evapotranspiration which prolongs the availability of soil water.

In this study, the objectives were 1) to compare the salt tolerance of 'TifEagle' and 'Champion' bermudagrass cultivars, 2) to evaluate the effect of biweekly TE applications on turfgrass quality and root biomass, and 3) to determine the interactive effects on P, K, Mg, Ca, and Na concentrations in above and belowground growth following TE and salt exposure.

Materials and Methods

This research included two repeated studies. Study I was conducted from 9 Jan. 2004 to 19 Mar. 2004. Greenhouse conditions averaged 23.3 °C/21.1 °C day/night temperature and 56% relative humidity. Study II was conducted from 19 Jan. 2004 to 29 Mar. 2004. Greenhouse conditions averaged day/night temperature of 24.4 °C/20.5 °C and 60% relative humidity.

Each study consisted of four treatments

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including a control with each cultivar replicated four times in a randomized complete block design. Plugs for the study were harvested from field research plots located on the Clemson University campus and transplanted into pots with 85% sand and 15% peat as growth media. Pot dimensions were 15.24 cm in height and 11.43 cm in diameter. Following potting, plugs were allowed to break dormancy and establish 1 month before initial treatments. Fertility was provided as nitrogen at 49 $kg\cdot ha^{-1}$ biweekly using a 16–4–8 fertilizer (including micronutrients as: Ca 6; Mg 3; S 9; B 0.06; Cu 0.03; Fe 0.3; Mn 0.15; Mo 0.0015; and Zn 0.15 kg ha^{-1}). Pots were mowed daily at 0.38 cm with clippings removed.

Salinity levels were 0, 12.90 (8,000 ppm), 25.80 (16,000 ppm), and 38.71 $dS\cdot m^{-1}$ (24,000 ppm). Appropriate NaCl levels were applied daily in 50 mL (equaling an irrigation of 2.7 mm) deionised distilled water. Trinexapac-ethyl applications were initiated 2 weeks after salinity exposure and applied four times in two week intervals at the active ingredient of 0.02 $kg\cdot ha^{-1}$. The emulsifiable concentrate (11.3% a.i.) of TE was used.

Since Study I and Study II were repeated studies, data collection was similar. Turf quality ratings were recorded weekly based on color, density, texture, and uniformity of the bermudagrass surface. Quality was visually evaluated from 1 to 9, 1 = brown, dead turf, 7 = minimal acceptable turf, 9 = ideal green, healthy turf. Clippings were harvested at week 10 for nutrient analysis. Roots were extracted from the soil and thoroughly washed until all soil was removed and then clipped from the base of the shoot tissue. Fresh weight of roots were then placed in an oven at 80.0 °C and dried for 48 hours. Once dried, samples were weighed to determine total root biomass. Roots and clippings were analyzed at the Clemson University testing laboratory for P, K, Ca, Mg, and Na concentration.

Nutrient analysis. For cation concentration determination and Na analysis, nitric acid (HNO_3) + 30% peroxide (H_2O_2) was used in a wet ash procedure. Plant material (0.50 g) was weighed and placed into a 100 mL digestion tube with 5 mL of HNO_3. Each digestion tube was heated at 125 °C for 1 h. Once tubes were heated and allowed to cool, 3 mL of 30% H_2O_2 was placed in each sample and heated at 200 °C or until samples dried. Plant tissue was then removed from the digestion tubes by adding 10 mL of 1:10 HNO_3 and diluted in 50 mL of deionized water and shaken vigorously. An inductively coupled plasma (ICP) autosampler (61E, Thermo Jarrell-Ash, Franklin, Mass.) was used to determine nutrient levels (Baldwin et al., 2005; Erickson et al., 2005).

Data analysis. All statistical computations were conducted using analysis of variance (ANOVA) within the Statistical Analysis System (SAS Institute, 1999). Due to limited root and shoot growth at the 38.71 $dS\cdot m^{-1}$ treatment, only the control, 12.50, and 25.80 $dS\cdot m^{-1}$ treatments were analyzed for nutrient concentrations. Data from both studies were combined as Study I × Study II interactions were not significant. Regression analysis was used to determine TQ growth response curves and to predict TQ scores. Interactions for root mass were not significant, therefore, only salinity, cultivar, and TE effects are reported. However, interactions for nutrient concentrations were significant, therefore, means were separated by Fisher's least significant difference (LSD) test. An alpha of 0.05 was used for all data comparisons.

Results and Discussion

Turfgrass quality (TQ). Unlike yield production crops, the most important measurement for turfgrass managers is TQ. Within each cultivar, TE improved TQ by providing a more dense turf with a darker green appearance (Fig. 1). At week 10, TE treated 'Champion' (8.8) had greater TQ than nontreated 'Champion' (7.1), while TE treated 'TifEagle' (7.8) had greater TQ than nontreated TE (7.0). Also, TE treated 'Champion' (8.8) had a greater TQ than nontreated 'TifEagle' (7.0) at week 10.

After 10 weeks of applying 12.90 $dS\cdot m^{-1}$ of NaCl, TE treated 'Champion' produced acceptable TQ (>7) ratings (Fig. 2). Lee et al. (2004) noted 'Tifgreen' and 'Tifway' bermudagrass tolerated 10 to 15 $dS\cdot m^{-1}$ of NaCl without TE. Without TE, at 12.90 $dS\cdot m^{-1}$, 'Champion' (≈6.9) consistently outperformed 'TifEagle' (≈5.7) at weeks 6 and 8. Significant improvements for TE treated 'TifEagle' (≈7.0) were noted compared to nontreated TE (≈5.9) at weeks 8 and 10.

At 25.80 $dS\cdot m^{-1}$, all cultivars, regardless of TE application, decreased in TQ (Fig. 3). Although all quality ratings were below 7.0, similar trends continued as nontreated 'Champion' had higher TQ scores than nontreated 'TifEagle' through week 10. Overall, at 25.80 $dS\cdot m^{-1}$, TE

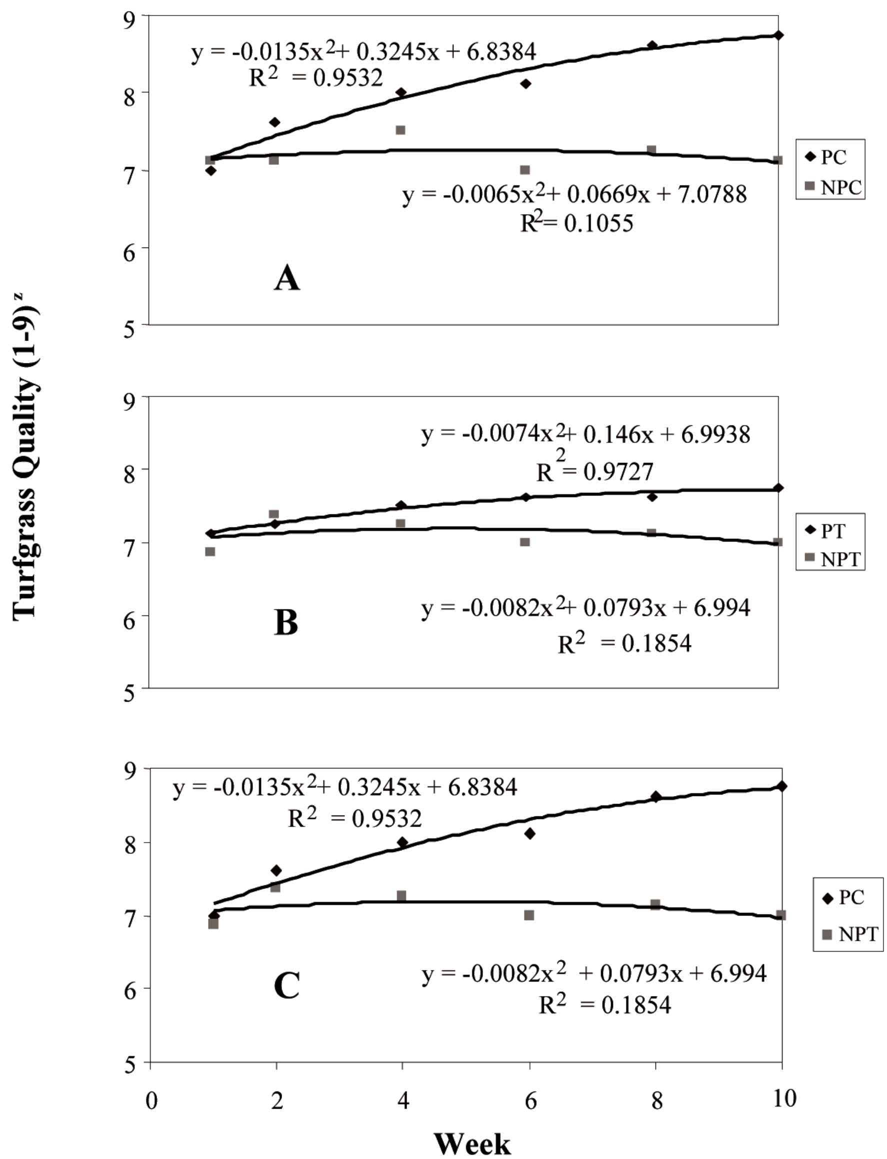

Fig. 1. Comparing four bi-weekly trinexapac-ethyl (0.02 $kg\cdot ha^{-1}$) applications beginning at week 2 and then reapplied every 2 weeks until week 8 on turfgrass quality of 'Champion' and 'TifEagle' bermudagrass without salinity: **(A)** PC vs. NPC, **(B)** PT vs. NPT, and **(C)** PC vs. NPT. PT = 'TifEagle' with trinexapac-ethyl, PC = 'Champion' with trinexapac-ethyl, NPT = 'TifEagle' without trinexapac-ethyl, NPC = 'Champion' without trinexapac-ethyl. Lines within each graph are statistically different at $p \leq 0.05$.

[z]Turfgrass quality based on a scale of 1 to 9, 1 = brown/dead turf, 7 = minimally acceptable turf, 9 = ideal green, healthy turf.

did not have a similar impact within cultivars as with the lower salt treatment (12.90 dS·m^{-1}).

Regression analysis predicted TE treated 'TifEagle' can tolerate 6.00 dS·m^{-1} (4,278 ppm), TE treated 'Champion' can tolerate 15.78 dS·m^{-1} (9,783 ppm), nontreated 'TifEagle' can tolerate 3.20 dS·m^{-1} (1,984 ppm) and nontreated 'Champion' can tolerate 8.70 dS·m^{-1} (5,394 ppm) of salt before dropping below an acceptable TQ rating of 7 (Fig. 4). Therefore, based on TQ when TE treated, this study suggests 'Champion' is tolerant to salinity levels less than 15.78 dS·m^{-1}, while 'TifEagle' is tolerant to salinity levels of less than 6.00 dS·m^{-1}.

Root biomass. Previous research indicates TE does not reduce root biomass for both warm-season and cool-season turfgrasses when exposed to non-saline pressure (Ervin and Koski, 2001; Fagerness and Yelverton, 2001; Fagerness et al., 2004; McCarty et al., 2004). This short-term greenhouse study indicated four applications of TE applied at 0.02 kg·a.i./ha for both cultivars averaged across all salinity treatments in two week intervals enhanced root growth by 25% (Fig. 5). Additionally, when comparing cultivar rooting, 'Champion' produced significantly greater total root biomass than 'TifEagle' averaged for all salinity and TE treatments (treated and nontreated) (Fig. 6). Increased root biomass under slight or moderate salinity stresses (Dudeck et al., 1983; Harivandi, 1992) may be one of the adaptive mechanisms by increasing the root absorbing surface to take up for more water. However, reduced root biomass was found as salinity treatments increased compared to the control in this study (Fig. 7). This may indicate that under low mowing putting green heights, with reduced photosynthesis, root reduction may likely occur in response to salinity stress above adaptive levels.

Nutrient analysis. Sodium (Na) levels increased 7 to 13 times in root tissue and 9 to 17 times in shoot tissue for both cultivars at the 25.80 dS·m^{-1} treatment compared to the control (Table 1). Dudeck and Peacock (1993) reported 7 to 14 times greater uptake of Na at 43 dS·m^{-1} in 'FSP-1' and 'FSP-3' seashore paspalum (*Paspalum vaginatum* Swartz.) and 'Tifway II' bermudagrass. In this research, both TE treated and nontreated cultivars averaged 261% greater Na in shoot tissue rather than root tissue at 25.80 dS·m^{-1}. This was expected as initial symptoms of salt stress include reduced shoot growth by turf thinning and leaf tip burning. At 25.80 dS·m^{-1}, compared to TE treated 'TifEagle' bermudagrass, nontreated 'TifEagle' had a 55% and 40% Na decrease in root and shoot tissue. Minimal Na reductions (≈6%) occurred in root and shoot tissue for TE treated 'Champion' bermudagrass compared to nontreated at 25.80 dS·m^{-1}.

At 12.90 and 25.80 dS m^{-1}, both TE treated ad nontreated cultivars shoot phosphorus (P) and potassium (K) levels were reduced an average 44% and 154%, respectively (Table 2). Similar reductions in K root tissue also occurred at 25.80 dS·m^{-1}, however, root P levels were unaffected by salinity or TE applications. These results are similar to Dudeck et al. (1983) which reported a reduction in K as Na levels increased in bermudagrass cultivars. Qian et al. (2000) noted a reduction in shoot K and an increase in shoot Na concentration in zoysiagrass cultivars at 42.5 dS·m^{-1}. In general, as NaCl treatments increased to 25.80 dS·m^{-1}, Ca and Mg reductions occurred in both root and shoot tissues (Table 3). Similar results were reported by Dudeck and Peacock (1993). Unlike P and K, TE treated turfgrass significantly enhanced Ca and Mg levels in shoot tissue compared to nontreated turf (Table 3). At 12.90 and 25.80 dS·m^{-1}, TE treated 'TifEagle' bermudagrass had 57% and 77% and TE treated 'Champion' had 25% and 20% greater Ca levels in shoot tissue compared to nontreated cultivars. Magnesium shoot concentration in TE treated 'Champion' and 'TifEagle' bermudagrass was 28% to 60% greater than the nontreated turf at 25.80 dS·m^{-1} (Table 3). Regardless of treatment or turfgrass, reductions in plant tissue P, K, Mg, and Ca were noted as salinity treatments increased.

Salinity stress may be worsened by reduction of roots, soil ion imbalances, and inefficient nutrient uptake or an interaction of these factors (Carrow et al., 2001). Although Ca^{+2} deficiencies are rare, turfgrass grown in high salinity soils may suffer reduced Ca^{+2} concentrations. Sodium

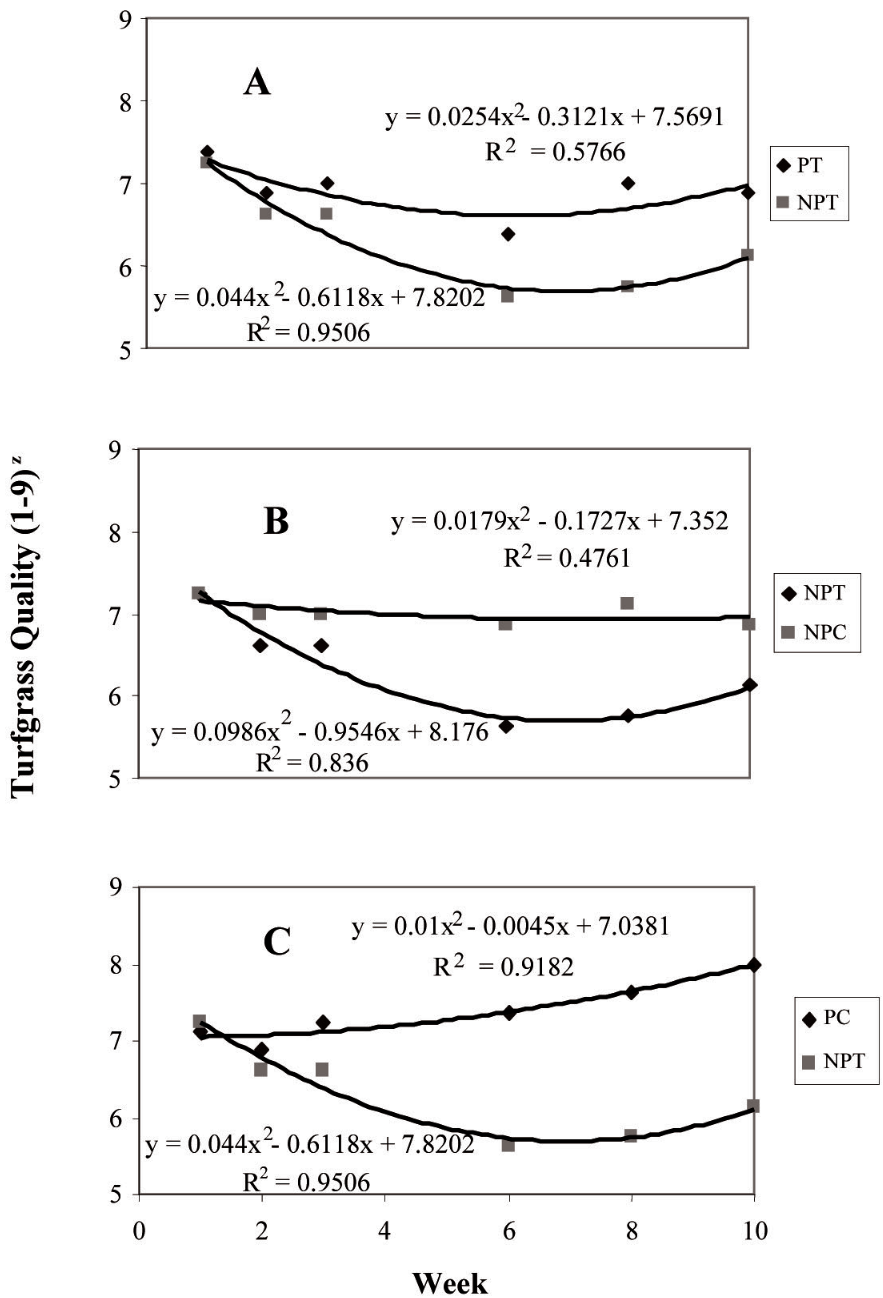

Fig. 2. Comparing salinity (12.90 dS·m^{-1}) and four biweekly trinexapac-ethyl (0.02 kg·ha^{-1}) applications beginning at week 2 and then reapplied every 2 weeks until week 8 on turfgrass quality of 'Champion' and 'TifEagle' bermudagrass : **(A)** PT vs. NPT, **(B)** NPT vs. NPC, and **(C)** PC vs. NPT. PT = 'TifEagle' with trinexapac-ethyl, PC = 'Champion' with trinexapac-ethyl, NPT = 'TifEagle' without trinexapac-ethyl, NPC = 'Champion' without trinexapac-ethyl. Lines within each graph are statistically different at $p \leq 0.05$.

[z]Turfgrass quality based on a scale of 1 to 9, 1 = brown/dead turf, 7 = minimally acceptable turf, 9 = ideal green, healthy turf.

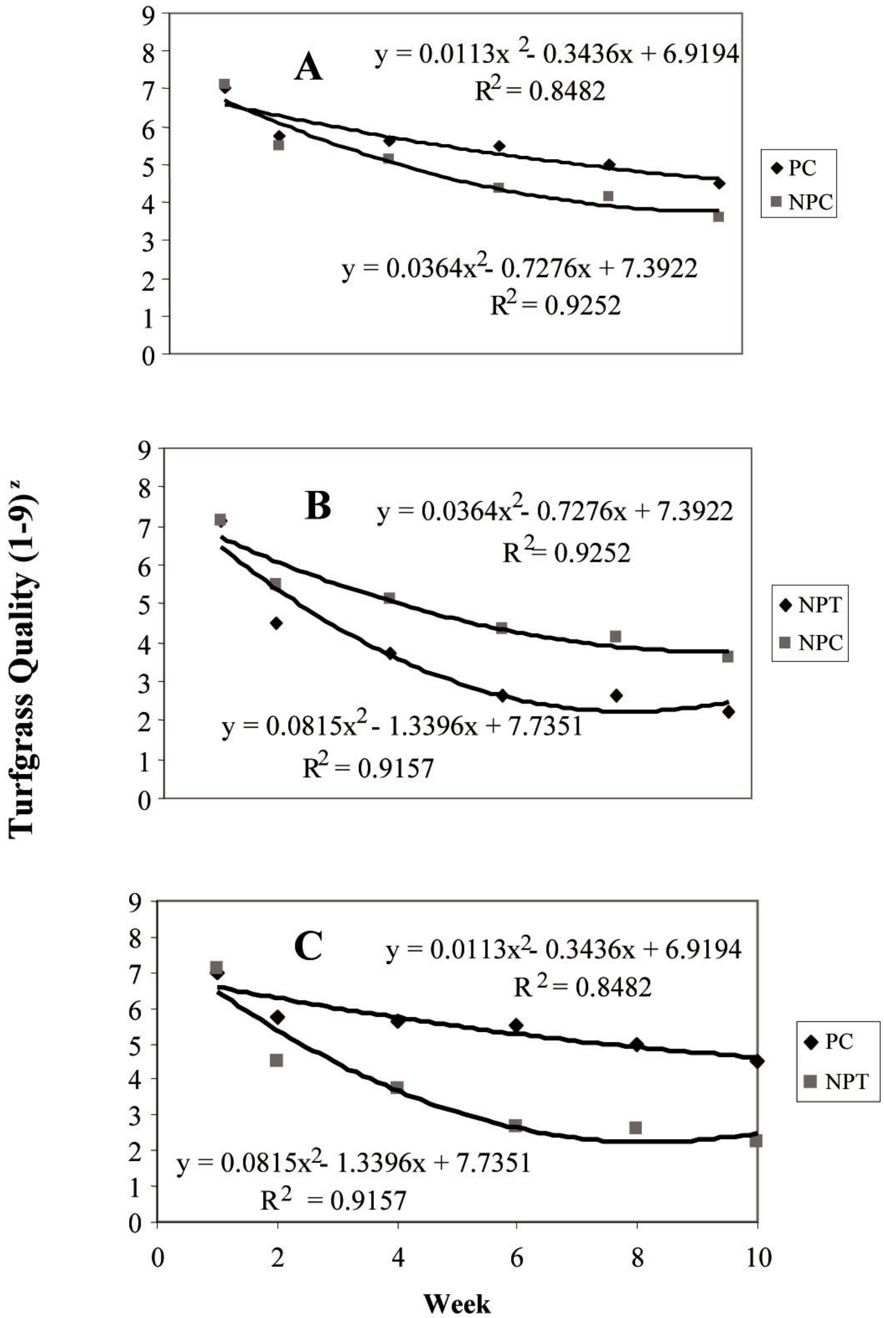

Fig. 3. Comparing salinity (25.80 dS·m^{-1}) and four bi-weekly trinexapac-ethyl (0.02 kg·ha^{-1}) applications beginning at week 2 and then reapplied every 2 weeks until week 8 on turfgrass quality of 'Champion' and 'TifEagle' bermudagrass : **(A)** PC vs. NPC, **(B)** NPT vs. NPC, and **(C)** PC vs. NPT. PT = 'TifEagle' with trinexapac-ethyl, PC = 'Champion' with trinexapac-ethyl, NPT = 'TifEagle' without trinexapac-ethyl, NPC = 'Champion' without trinexapac-ethyl. Lines within each graph are statistically different at $p \leq 0.05$.

[z]Turfgrass quality based on a scale of 1 to 9, 1 = brown/dead turf, 7 = minimally acceptable turf, 9 = ideal green, healthy turf.

can displace Ca^{+2} on cation exchange sites in the soil and also from the cell membrane reducing cell membrane ion exclusion and selective transport (Carrow and Duncan, 1998). Potassium in turfgrasses may be depressed due to existing Na^+ and added Ca^{+2}. This study agrees with other reviews or reports (Carrow and Duncan, 1998; Harivandi, 1992; Marcum, 1999; Lee et al., 2004) that under salinity stress, additional applications of Ca, K, Mg, and P may reduce ion imbalance in the soil.

Conclusions

'Champion' and 'TifEagle' bermudagrass are tolerant to salt levels less than 15.78 and 6.00 dS·m^{-1} with TE application, respectively. Without TE, 'TifEagle' (6.1) had lower TQ than 'Champion' (6.9) after 10 weeks of applying 12.90 dS·m^{-1}. Also, at the 12.90 dS·m^{-1} treatment, TE treated 'Champion' was the only turfgrass with an acceptable TQ rating (>7) after 10 weeks. Salinity impacted root growth

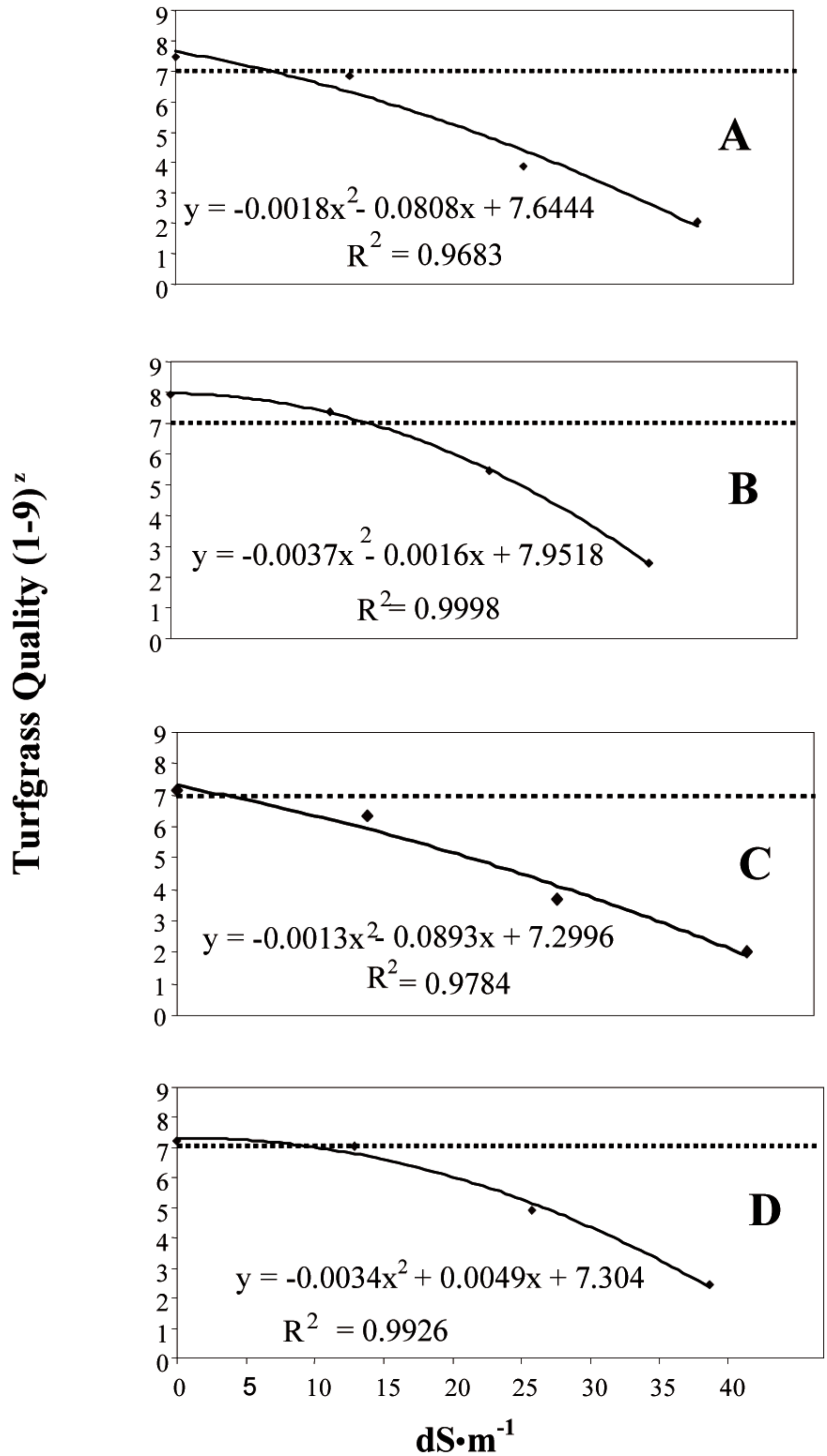

Fig. 4. Predicted turfgrass quality responses of **(A)** PT, **(B)** PC, **(C)** NPT, and **(D)** NPC to various salinity levels. Abbreviations: PT = 'TifEagle' with trinexapac-ethyl, PC = 'Champion' with trinexapac-ethyl, NPT = 'TifEagle' without trinexapac-ethyl, NPC = 'Champion' without trinexapac-ethyl. Lines indicate minimal acceptable turf quality (7).

[z]Turfgrass quality based on a scale of 1 to 9, 1 = brown/dead turf. 7 = minimally acceptable turf, 9 = ideal green, healthy turf.

within each cultivar. Trinexapac-ethyl application increased root growth by 25% for both cultivars. In addition, salinity levels impacted nutrient levels in both cultivars. Sodium concentration increased an average 261% in shoot tissue compared to root tissue for TE treated and nontreated cultivars. Reductions in plant tissue P, K, Mg, and Ca concentrations in both

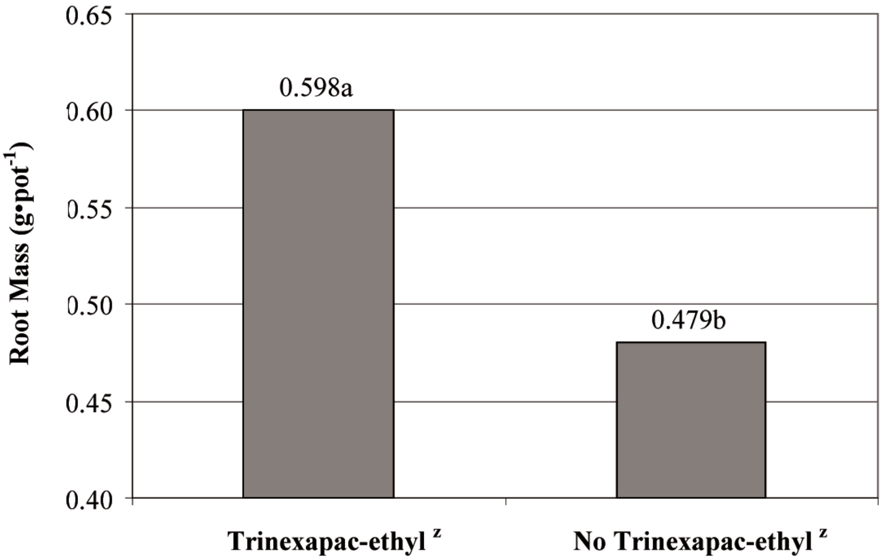

Fig. 5. Combined root mass (g) of 'Champion' and 'TifEagle' bermudagrass following four applications of trinexapac-ethyl at 0.02 kg·a.i./ha when exposed to 0, 12.90, 25.80, and 38.71 dS·m^{-1} of sodium chloride.

[z]Mean data points followed by the same letter are not significantly different at $p \leq 0.05$.

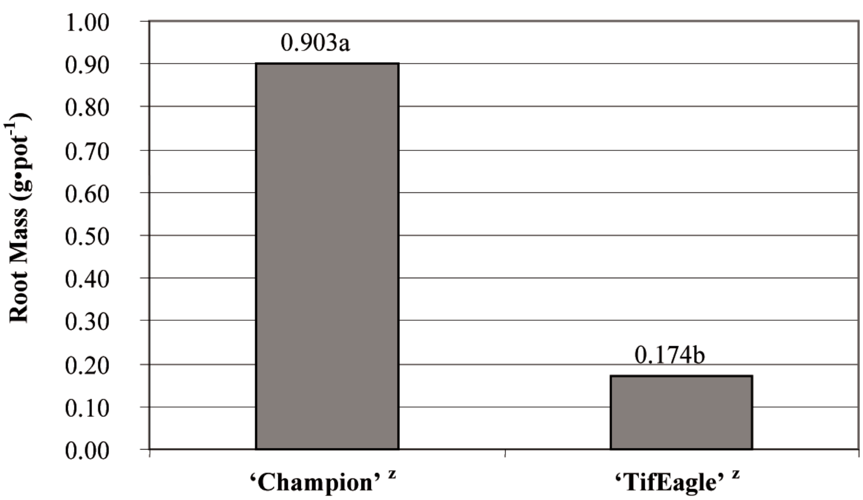

Fig. 6. Comparison of 'Champion' and 'TifEagle' bermudagrass root weight when exposed to 0, 12.90, 25.80, and 38.71dS·m^{-1} of sodium chloride with and without trinexapac-ethyl.

[z]Mean data points followed by the same letter are not significantly different at $p \leq 0.05$.

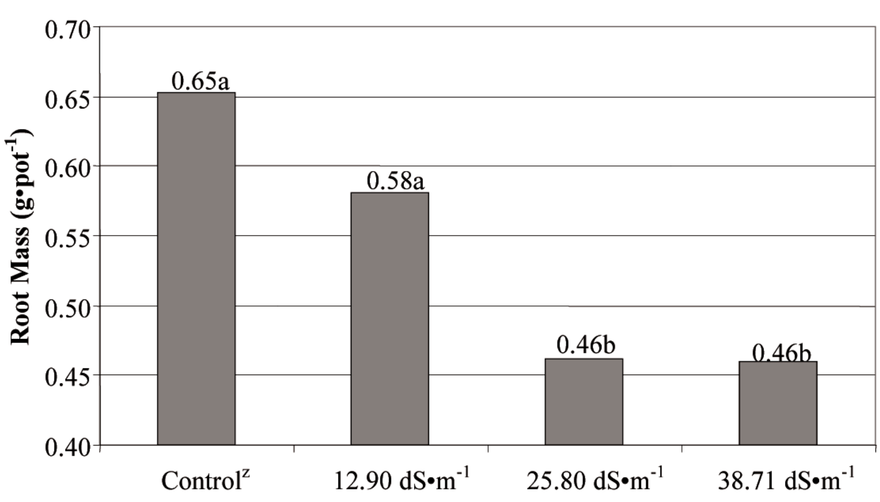

Fig. 7. Combined root mass (g) of 'Champion' and 'TifEagle' bermudagrass following 10 weeks of salinity application at 12.90, 25.80, and 38.71 dS·m^{-1} of sodium chloride.

[z]Within salinity levels, mean data points followed by the same letter are not significantly different.

cultivars (TE treated and nontreated) were noted as salinity treatments increased.

From this greenhouse study, the two bermudagrass cultivars responded differently when exposed to moderate levels of NaCl. Future studies could focus on other ultradwarf bermudagrass cultivars, such as 'MiniVerde', 'MS-Supreme', 'Tifdwarf', and 'FloraDwarf'. Also, salinity levels should be reduced to focus on TE's effect on TQ at lower NaCl levels as 25.80 and 38.71 dS·m^{-1} were toxic to both cultivars. Also, initiating TE applications before salt stress becomes prevalent may improve the grasses response to increased salinity. Finally, rather than applying NaCl daily, cycling fresh water weekly may also improve turfgrass response.

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Table 1. Sodium concentration (dS·m^{-1}) in two bermudagrass cultivars shoot and root tissue treated with and without trinexapac-ethyl and exposed to 0, 12.90, and 25.80 dS·m^{-1} of sodium chloride.

	Na concn (dS·m^{-1})					
	Root tissue			Shoot tissue		
Turf	Control	12.90	25.80	Control	12.90	25.80
PT[z]	1.95 a[y]	6.53	18.06 a	3.05	31.92	52.70 a
PC	1.08 b	7.36	12.16 b	4.04	33.41	50.10 b
NPT	1.72 a	7.00	11.61 b	3.97	25.26	37.69 b
NPC	0.93 b	7.43	12.88 b	3.62	28.74	53.77 a
LSD	0.42	1.93	4.32	1.48	7.38	7.28
p value	0.01[x]	0.77	0.02	0.53	0.13	0.01

[z]PT = 'TifEagle' with trinexapac-ethyl, PC = 'Champion' with trinexapac-ethyl, NPT = 'TifEagle' without trinexapac-ethyl, NPC = 'Champion' without trinexapac-ethyl.
[y]Values within a column followed by the same letter are not significantly different at $P \leq 0.05$ by protected LSD.
[x]Indicates statistical difference at $p \leq 0.05$.

Table 2. Phosphorus (P) and potassium (K) concentration in shoot and root tissue of 'Champion' and 'TifEagle' bermudagrass with and without exposure to 12.90 and 25.80 dS·m^{-1} of sodium chloride.

	P concn (%)						K concn (%)					
	Root tissue			Shoot tissue			Root tissue			Shoot tissue		
Turf	Control	12.90	25.80	Control	12.90	25.80	Control	12.90	25.80	Control	12.90	25.80
PT[z]	0.11	0.16 a[y]	0.11	0.60	0.45	0.37	0.39	0.18 bc	0.09b	2.76	1.47 b	0.80 c
PC	0.10	0.13 ab	0.14	0.55	0.47	0.42	0.45	0.21 ab	0.13 a	3.04	1.59 a	1.05 a
NPT	0.10	0.10 b	0.13	0.61	0.46	0.35	0.33	0.15c	0.11ab	3.03	1.62 a	0.93 b
NPC	0.10	0.11 b	0.11	0.62	0.47	0.38	0.41	0.23 a	0.12 a	3.13	1.62 a	0.98 ab
LSD	0.02	0.04	0.03	0.08	0.05	0.07	0.12	0.04	0.03	0.31	0.09	0.10
p value	0.22[x]	0.02	0.15	0.48	0.90	0.36	0.19	0.01	0.04	0.10	0.01	0.01

[z]PT = 'TifEagle' with trinexapac-ethyl, PC = 'Champion' with trinexapac-ethyl, NPT = 'TifEagle' without trinexapac-ethyl, NPC = 'Champion' without trinexapac-ethyl.
[y]Values within a column followed by the same letter are not significantly different at $P \leq 0.05$ by protected LSD.
[x]Indicates statistical difference at $p \leq 0.05$.

Table 3. Magnesium (Mg) and calcium (Ca) concentration in shoot and root tissue of 'Champion' and 'TifEagle' bermudagrass with and without exposure to 12.90 and 25.80 dS·m^{-1} of sodium chloride.

	Mg concn (%)						Ca concn (%)					
	Root tissue			Shoot tissue			Root tissue			Shoot tissue		
Turf	Control	12.90	25.80	Control	12.90	25.80	Control	12.90	25.80	Control	12.90	25.80
PT[z]	0.18	0.06	0.06	0.22 a[y]	0.10	0.08 a	0.18	0.12	0.18 a	0.27 a	0.22 a	0.23 a
PC	0.12	0.06	0.04	0.20 a	0.10	0.09 a	0.21	0.10	0.11 b	0.25 ab	0.15 ab	0.18 b
NPT	0.10	0.08	0.04	0.17 b	0.09	0.05 b	0.16	0.11	0.11 b	0.19 c	0.14 b	0.13 b
NPC	0.12	0.06	0.04	0.19 ab	0.09	0.07 b	0.20	0.11	0.12 b	0.21 bc	0.12 b	0.15 bc
LSD	0.07	0.02	0.02	0.03	0.02	0.03	0.05	0.02	0.04	0.05	0.07	0.05
p value	0.94[x]	0.21	0.63	0.01	0.68	0.04	0.15	0.66	0.01	0.01	0.04	0.01

[z]PT = 'TifEagle' with trinexapac-ethyl, PC = 'Champion' with trinexapac-ethyl, NPT = 'TifEagle' without trinexapac-ethyl, NPC = 'Champion' without trinexapac-ethyl.
[y]Values within a column followed by the same letter are not significantly different at $P \leq 0.05$ by protected LSD.
[x]Indicates statistical difference at $p \leq 0.05$.

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