Chapter Three: The Influence of Trinexapac-ethyl on Creeping Bentgrass Golf Putting Green Nitrogen Requirements

ABSTRACT

The plant growth regulator trinexapac-ethyl (TE) has been reported to reduce clipping yield and increase numerous turfgrass attributes including color, visual quality, and tiller density. Typically, these changes are also achieved by increasing nitrogen application rate, yet few have comprehensively investigated the effect of TE on turfgrass nitrogen requirements. It was hypothesized that application of TE to creeping bentgrass (*Agrostis stolonifera* Hud.) putting greens can reduce nitrogen application rates with no detriment to turfgrass color or quality. A three year study was conducted on a creeping bentgrass putting green where three biweekly N application rates (5, 10, 20 kg N ha^{-1}) where applied with or without TE application. In the first year, TE was applied at the labeled application rate of 0.05 kg a.i. ha^{-1} every three weeks. During the final two years, TE was applied at the rate of 0.10 kg a.i. ha^{-1} every 200 growing degree days (GDD; base 0°C). Turfgrass yield, color, and visual quality quantified biweekly, and tissue nitrogen content analyzed monthly. Clipping yield, tissue N content, color, and visual quality increased with increasing with N rate in all three years. Quality enhancement and clipping suppression caused by TE application every three weeks were inconsistent during year one. The 200 GDD TE re-application interval sustained turfgrass color and quality enhancements and maintained yield suppression in 2009-10. Nitrogen removal due to mowing was reduced by 13% with TE application. Trinexapac-ethyl applications reduced clipping yield by the same magnitude as reducing N fertilize rate by 50%. Enhancements in color and quality

with 200 GDD TE applications allow for reduction of N rate by approximately 25% with no detriment to turfgrass quality or color.

INTRODUCTION

Turfgrass growth clipping yield, color, and visual quality are altered via two common management practices, application of nitrogen containing fertilizer and the plant growth regulator trinexapac-ethyl (TE). Application of nitrogen fertilizer is traditionally used to enhance these attributes because nitrogen is the most limiting soil nutrient in a turfgrass system (Christians, 1979). Research by Houlihan (2005) indicated that creeping bentgrass (*Agrostis stolonifera* Hud.) and Kentucky bluegrass (*Poa pratensis* L.) clipping yield responded up to annual rates of 517 and 780 kg N ha^{-1} respectively. These rates are typically four to eight times greater than most university recommendations. Therefore, maximizing yield is not the factor which determines annual nitrogen application rates in turfgrass. Nitrogen recommendations for golf course putting greens are traditionally based on the annual N needed to maintain turfgrass recuperative potential and visual quality that is deemed acceptable by the golfing public, and typically range from 100 to 250 kg ha^{-1} annually (McCarty, 2005).

Trinexapac-ethyl application to golf putting greens has become a common practice since it was released as Primo in the early 1990s (Syngenta Co., Greensboro, NC). Trinexapac-ethyl affects many of the same turfgrass attributes as nitrogen fertilization; i.e. clipping yield, color, tiller density, etc. (Ervin and Zhang, 2008). Unlike nitrogen however, TE suppresses turfgrass clipping yield by inhibiting synthesis of the plant hormone gibberellic acid, GA_1 (Rademacher, 2000). The product label states the 0.05 kg a.i. ha^{-1} application rate will inhibit clipping yield by 50% for a period of four weeks. However, researchers have noted that TE only typically provides 20% or less growth suppression on creeping bentgrass putting greens for a duration dependent upon air temperature but typically less than four weeks (McCullough et al., 2006b)

Nutrient removal for putting greens is a function of clipping yield and tissue nutrient content and serve as a guide for estimating N fertilizer requirements (McCarty, 2005). In addition to reducing nutrient removal by suppressing clipping yield, TE has been reported to cause nutrient re-distribution or partitioning from the turfgrass leaves to the roots leaving N uptake unaffected (Fagerness et al., 2004; McCullough et al., 2006a). Therefore, reduced clipping yield and clipping nutrient content will reduce nutrient removal and potentially diminish fertilizer requirements.

In addition to decreased clipping yield, multiple TE applications increase turfgrass visual quality, color, and shoot density similarly to nitrogen fertilization (Ervin and Zhang, 2008, Ervin and Koski, 1998; Beasley and Branham, 2007; Stier et al., 1999; Qian and Engelke, 1999). These enhancements occur because reduced levels of GA_1 causes reduced leaf cell length and increased mesophyll cell density, chlorophyll concentrations, and cytokinin concentration (Ervin and Koski, 2001; Stier and Rodgers, 2001; Bunnell et al., 2005). Stier et al. (1999) showed that plant growth regulator application rate affected the magnitude of these enhancements.

We hypothesized that repeat applications of TE to creeping bentgrass putting greens would reduce annual nitrogen requirements by reducing nutrient removal during mowing and through enhancement of turfgrass visual quality and color which are the principle responses used for determination of annual N rate. The objective of this study was to evaluate the effect of biweekly nitrogen application rate and TE on creeping bentgrass yield, color, visual quality, and clipping tissue total nitrogen content. Evaluations of these various responses will elucidate differences in creeping bentgrass N requirements as influenced by multiple TE applications.

METHODS

Site Description and Experimental Design

A field experiment was conducted on a creeping bentgrass (‘Memorial’) putting green research plot at the OJ Noer Turfgrass Research and Education Facility in Madison, WI during 2008 to 2010. The green was constructed in the fall of 2006 to USGA specifications for putting green construction with a peat-amended (20% by volume) sand root zone (USGA Green Section Staff, 2004). During the three years of the study, the green was mowed 6 d wk^{-1} at 3.2 mm with a Toro Greensmaster 1000 (Toro Co., Bloomington, MN). Overhead irrigation supplemented precipitation to 80% of estimated evapotranspiration daily. Sand topdressing was applied to a surface depth of 1-2 mm during October of 2007 and 2008 (fines free topdressing sand, Waupaca Sand & Solutions, Waupaca, WI). Hollow-tine aeration occurred in two directions on 25 May and 10 September 2009 and 29 March 2010 with a Toro Greens Aerator (Toro Co., Bloomington, MN). Tine spacing and diameter were 5.1 and 1.9 cm respectively. Cores were removed and filled with sand topdressing. Chlorothalonil applications were used to control turfgrass disease during all years. Annual soil testing indicated that P and K were sufficient during all four years of the experiment although maintenance applications of P and K were applied periodically.

Plots measured 2.4 x 1.8 m and were arranged in a randomized complete block design with six treatments and four blocks. Treatments consisted of a 3x2 factorial of three biweekly liquid urea (46-0-0) nitrogen rates (5, 10, 20 kg N ha^{-1}) and two TE application rates. Maintenance nitrogen applications were applied to the entire plot during the late fall and early spring between the active summer research season and were credited to the following season's total annual N fertility. A detailed description of all fertilization is included in Table 3.1.

During 2008, TE treatments were applied at the rates of 0.00 and 0.05 kg a.i. ha^{-1} every three weeks. This treatment was amended for 2009-10 to 0.10 kg a.i. ha^{-1} applied every 200 growing degree days (GDD) in an effort sustain consistent growth suppression during the entire growing season. Cumulative GDD after TE application was the summation of daily average air temperature (base 0°C) where TE was re-applied and GDD reset to 0 after the 200 GDD threshold had been surpassed. Both TE and nitrogen fertilizers were applied with a CO_2 powered backpack sprayer with TeeJet AI 11004 nozzles calibrated to deliver 800 L ha^{-1} at 276 kPa. Irrigation to a depth of 5 mm was applied immediately following N applications. Applications occurred from 21 May to 9 Sept 2008, 11 May to 17 Aug 2009, and 1 April to 11 July 2010 (Table 3.2).

Table 3.1. The fertility record for all three nitrogen treatments during years one, two, and three.

Date	Fertilizer	N			P	K
		High	Med	Low	All	All
Season 2	N-P-K	kg ha^{-1}				
7 May 2008	18-4-15†	24	24	24	5	20
13 May 2008	14-12-10§	10	10	10	8	7
20 May 2008	0-23-28¶	0	0	0	32	40
5 June 2008	46-0-0‡	20	10	5	0	0
12 June 2008	46-0-0‡	20	10	5	0	0
20 June 2008	0-0-37#	0	0	0	0	40
2 July 2008	46-0-0‡	20	10	5	0	0
16 July 2008	46-0-0‡	20	10	5	0	0
21 July 2008	46-0-0‡	20	10	5	0	0
13 August 2008	46-0-0‡	20	10	5	0	0
28 August 2008	46-0-0‡	20	10	5	0	0
9 September 2008	46-0-0‡	20	10	5	0	0
Season 1 Total		190	112	73	46	107
24 October 2008	46-0-0‡	24	24	24	0	0
11 May 2009	46-0-0‡	20	10	5	0	0
19 May 2009	0-23-28¶	0	0	0	5	6
28 May 2009	46-0-0‡	20	10	5	0	0
9 June 2009	46-0-0‡	20	10	5	0	0
23 June 2009	46-0-0‡	20	10	5	0	0
7 July 2009	46-0-0‡	20	10	5	0	0
22 July 2009	46-0-0‡	20	10	5	0	0
4 August 2009	46-0-0‡	20	10	5	0	0
17 August 2009	46-0-0‡	20	10	5	0	0
Season 2 Total		181	102	63	5	6
Season 3						
2 September 2009	46-0-0‡	20	20	20	0	0
16 September 2009	46-0-0‡	15	15	15	0	0
30 March 2010	46-0-0‡	20	10	5	0	0
30 March 2010	0-23-28¶	0	0	0	5	6
20 April 2010	46-0-0‡	20	10	5	0	0
6 May 2010	46-0-0‡	20	10	5	0	0
20 May 2010	46-0-0‡	20	10	5	0	0
20 May 2010	0-23-28¶	0	0	0	10	12
8 June 2010	46-0-0‡	20	10	5	0	0
24 June 2010	46-0-0‡	20	10	5	0	0
6 July 2010	46-0-0‡	20	10	5	0	0
Season 3 Total		175	105	70	15	18

† Granular Anderson's Contec DG
‡ Liquid feed-grade urea
§ Granular Spring Valley greens starter
¶ Liquid Monopotassium phosphate
# Liquid potassium sulfate

Table 3.2. Trinexapac-ethyl application dates and rates to appropriate treatments.

Experiment Year	Re-application Interval	Date	Application Rate
One	3 Week	5 June 2008	0.05
One	3 Week	26 June 2008	0.05
One	3 Week	16 July 2008	0.05
One	3 Week	7 August 2008	0.05
One	3 Week	28 August 2008	0.05
One	3 Week	18 September 2008	0.05
Two	200 GDD†	11 May 2009	0.10
Two	200 GDD	20 May 2009	0.10
Two	200 GDD	3 June 2009	0.10
Two	200 GDD	15 June 2009	0.10
Two	200 GDD	25 June 2009	0.10
Two	200 GDD	6 July 2009	0.10
Two	200 GDD	15 July 2009	0.10
Two	200 GDD	27 July 2009	0.10
Two	200 GDD	10 August 2009	0.10
Two	200 GDD	22 August 2009	0.10
Three	200 GDD	1 April 2010	0.10
Three	200 GDD	19 April 2010	0.10
Three	200 GDD	5 May 2010	0.10
Three	200 GDD	21 May 2010	0.10
Three	200 GDD	1 June 2010	0.10
Three	200 GDD	11 June 2010	0.10
Three	200 GDD	22 June 2010	0.10
Three	200 GDD	2 July 2010	0.10
Three	200 GDD	11 July 2010	0.10

† Growing degree day (GDD) is the summation of mean daily air temperature (base 0°C) after trinexapac-ethyl application. After 200 GDD trinexapac-ethyl was re-applied and the GDD model was reset to zero.

Data Collection

Clipping yield, turfgrass overall visual quality, and color index were recorded biweekly prior to N fertilization. Biweekly data collection occurred from 5 June to 23 Sept 2008, 26 May to 1 September 2009, and 6 May to 15 July 2010. Clippings were collected by mowing one 1.9 m pass down the center of each plot 24 h (± 2 h) following previous mowing. Prior to clipping collection, 27 cm buffer alleys were mowed at the top and bottom of each plot to reduce variation cause by starting and stopping the mower. Clippings were then brushed from the mower collection bucket into a paper bags before being placed in a drying oven for 24h at 60°C. Sand debris was removed and clipping mass was recorded prior to being passed through a Wiley mill (Thomas Scientific, Swendesboro, NJ). Ground clippings from one rating day per month in 2009 and 2010 were sent to the University of Wisconsin Soil and Plant Analysis Laboratory (SPAL) for total N analysis using flow digestion analysis (Lachat Instruments, Loveland, CO) following a Kjeldahl digestion. Nitrogen removal was calculated by multiplying clipping yield by dry tissue N content.

Turfgrass visual quality was rated on a 1 to 9 scale with 1 representing completely dead, 6 minimally acceptable, and 9 perfect putting green quality. Turfgrass color was quantified with 10 measurements of color index with a CM-1000 reflectometer (Spectrum Technologies, Inc, Plainfield, IL) on a 0-999 scale. The CM-1000 was held one meter from the turfgrass surface with the incidental light meter pointed in the direction of the sun.

Statistical Analysis

JMP software was used for all statistical analysis (version 8.0.2, SAS Institute, Cary, NC). Clipping yield, color index, turfgrass quality, N content, N uptake/removal were subject to repeated measures analysis with standard least squares personality and REML method. Year one was analyzed separately from year two and three due to differences in TE application rate and frequency. Means were separated with Fishers Protected LSD (α=0.05) when appropriate.

RESULTS AND DISCUSSION

Clipping Yield

The nitrogen rate, rating date, and nitrogen rate x date interaction strongly affected clipping yield directly during all three years (Tables 3.3 and 3.4). Clipping yield increased with increased N fertilizer application rate (Figure 3.1). During year one, the tri-weekly TE applications did not significantly affect clipping yield (Table 3.3), likely because post-inhibition grown enhancement balanced yield suppression (Fagerness and Yelverton, 2000). There was a significant date by TE interaction in 2008 (Figure 3.1). Trinexapac-ethyl reduced clipping yield on 12 June and 10 July 2008. On all other 2008 rating days clipping yield was not significantly affected by TE. As a result, TE decreased net yield by a non-significant 6% during year one. In contrast, TE applications every 200 GDD in 2009 and 2010 significantly reduced clipping yield by 16.2% (Table 3.4). This level of yield suppression is consistent with McCullough et al. (2006b) and chapter two of this thesis, which demonstrated that post-inhibition growth enhancement can be eliminated by re-applying TE every 200 GDD (base 0°C).

The TE x date interaction resulted from a single rating day in July 2009 where clipping yields were not affected by TE (Figure 3.1). There was an N x TE interaction in years two and three (Table 3.5). The magnitude of clipping suppression with TE was greatest at the highest N fertilizer rate. Although the magnitude of yield suppression is greater with increasing N rate, relative clipping yield suppression was not significantly different regardless of nitrogen rate; 16.7, 7.0, and 22.9% for the 5, 10, and 20 kg ha^{-1} N treatments, respectively. There are several significant year interactions. These effects are was likely caused by the lack of season-long data collection in year three, i.e. fewer summer rating days to counter early spring ratings, and possibly because a different Toro 1000 greens mower was used in year three.

During 2009 and 2010, the 10 and 20 kg ha^{-1} N treatments that received TE every 200 GDD had statistically similar yields as the 5 and 10 kg ha^{-1} N treatments that were not treated with TE, respectively (Table 3.5). This result did not occur in 2008 when TE was applied every three weeks. Switching TE application frequency cannot be solely attributed to increased yield suppression in years two and three because TE application rate was also increased from year one in this study. However, McCullough et al. (2007) showed that application rate had limited effect on magnitude and duration of growth suppression. Additionally, Chapter 2 in the thesis found that 0.05 and 0.10 application rates did not alter significantly the magnitude or duration of yield suppression on a creeping bentgrass putting green. Therefore, the more appropriate 200 GDD TE application interval, not the increased application rate, was assumed responsible for the sustained yield suppression in 2009 and 2010. Based on the results in Table 3.5, TE reduced clipping yield to a similar extent as reducing N rate by 50%.

Table 3.3. F ratios and *p*-values from ANOVA for treatment, year, and date effects on turfgrass attributes during year one (2008) of this study.

Source	df	Clipping Yield		Quality		Color Index	
		F Ratio	p-value	F Ratio	p-value	F Ratio	p-value
Nitrogen (N)	2	21.94	<0.0001***	25.92	<0.0001***	99.10	0.0006***
Trinexapac-ethyl (TE)	1	1.16	0.2978	1.65	0.2181	2.12	0.1657
Date	9	63.55	<0.0001***	18.67	<0.0001***	60.63	<0.0001***
N x TE	2	0.34	0.7180	1.27	0.3102	2.29	0.1351
N x Date	18	3.57	0.0006***	7.70	<0.0001***	7.45	<0.0001***
TE x Date	9	2.57	0.0316*	1.53	0.1635	1.18	0.3050
N x TE x Date	18	1.85	0.0639	1.61	0.0842	0.37	0.9938

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.

Table 3.4. F ratios and *p*-values from ANOVA for treatment, year, and date effects on turfgrass attributes during years two and three (2009-2010) of this study.

Source	df	Clipping Yield		Quality		CI		Tissue N		N Removal	
		F Ratio	p-value	F Ratio	p-value	F Ratio	p-value	F Ratio	p-value	F Ratio	p-value
Nitrogen (N)	2	62.52	<0.001***	209.04	<0.001***	18.83	<0.001***	380.20	<0.001***	59.11	<0.001***
Trinexapac-ethyl (TE)	1	22.68	<0.001***	39.53	<0.001***	3.45	0.082	28.90	<0.001***	9.95	0.006**
Year (Yr)	1	1044.49	<0.001***	23.10	<0.001***	124.13	<0.001***	361.00	<0.001***	344.55	<0.001***
Date [Yr]	6	256.32	<0.001***	53.31	<0.001***	137.18	<0.001***	388.23	<0.001***	443.75	<0.001***
N x TE	2	4.35	0.032*	0.16	0.850	0.3036	0.742	0.46	0.637	2.11	0.156
N x Yr	2	38.59	<0.001***	11.17	<0.001***	1.34	0.265	23.56	<0.001***	17.04	<0.001***
TE x Yr	1	9.62	0.002**	12.46	<0.001***	2.18	0.143	9.34	0.002**	6.46	0.012*
N x TE x Yr	2	3.32	0.038*	3.58	0.029*	0.31	0.736	1.52	0.220	0.34	0.713
N x Date [Yr]	12	8.00	<0.001***	4.10	<0.001***	2.84	0.002**	6.56	<0.001***	19.64	<0.001***
TE x Date [Yr]	6	3.38	<0.001***	3.48	<0.001***	0.83	0.551	2.78	<0.001***	3.35	0.004**
N x TE x Date [Yr]	12	4.25	<0.001***	1.82	0.007**	0.65	0.796	1.49	0.051	2.75	0.003**

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.

Table 3.5. The effect of N rate and trinexapac-ethyl (TE) application on turfgrass clipping yield, visual quality (1-9 scale; 1 is dead, 6 minimally acceptable, and 9 perfect turfgrass quality), color index, clipping tissue N content, and N removal. There was a significant TE x N interaction for clipping yield.

N Rate	TE	Clipping Yield	Visual Quality	Color Index	Tissue N	N Removal
kg ha^{-1}	kg a.i. ha^{-1}	Dry WT g m^{-2}	1-9 Scale	0-999	% Dry Wt	mg N m^{-2}
5	0.0	3.30 DE	5.9 E	212 F	2.80 D	93.6 CD
10	0.0	3.87 BC	6.9 D	235 D	2.93 CD	111.0 C
20	0.0	5.67 A	7.9 B	279 B	3.10 AB	171.1 A
5	0.1	2.75 E	6.3 E	220 E	2.83 D	80.1 D
10	0.1	3.60 CD	7.4 C	248 C	3.04 BC	105.8 C
20	0.1	4.37 B	8.3 A	291 A	3.21 A	140.0 B

Column means followed by different letters are statistically different according to Fisher's LSD at α=0.05

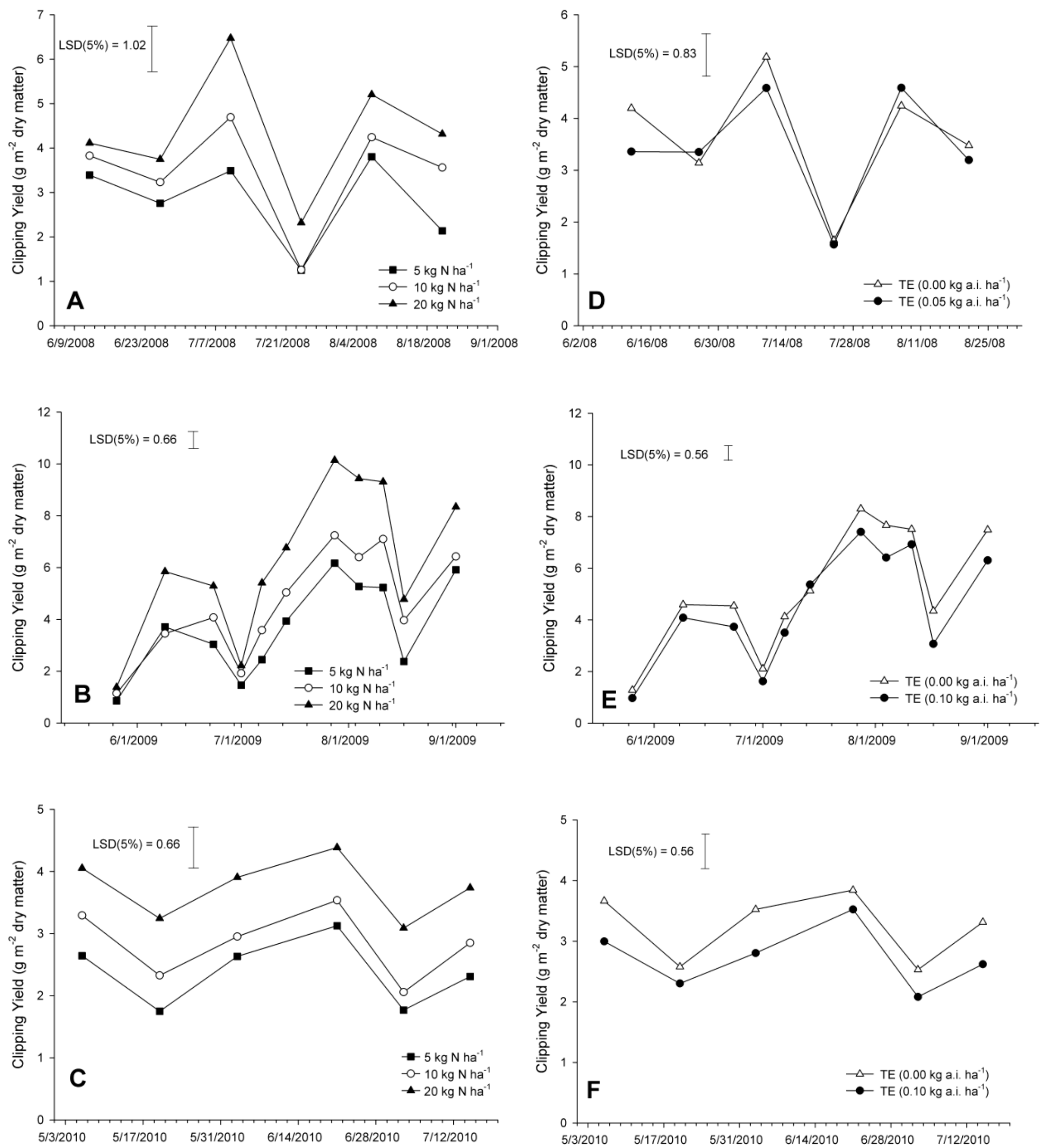

Figure 3.1. The effect of biweekly nitrogen rate (5, 10, 20 kg N ha^{-1}) and trinexapac-ethyl (TE) on clipping yield during 2008 (A and D), 2009 (B and E), and 2010 (C and F). TE was applied every three weeks at 0.05 kg a.i. ha^{-1} in 2008. During 2009 and 2010, TE was applied every 200 GDD at the rate of 0.10 kg a.i. ha^{-1}. GDD was the summation of mean daily air temperature, base 0°C, after TE application. After 200 GDD, TE was re-applied and the model was reset to zero.

Clipping N Content and N Removal

Nitrogen rate, date, year, and N x date significantly affected tissue N content (Table 3.4). Clipping tissue N content increased with N application rate (Table 3.5). Treatments that received TE application had greater clipping N content at α=0.10. This finding is in contrast to reports of decreased clipping N content following TE application on creeping bentgrass and hybrid bermudagrass (Fagerness et al., 2004; McCullough et al., 2006a). Clipping N contents from the 5 and 10 kg ha^{-1} N treatments that received TE were statistically similar (α=0.05) to the 10 and 20 kg ha^{-1} N treatments that were not treated with TE, respectively.

Increasing N application rate increased N removal because increased clipping yield and clipping N content (Table 3.4). Trinexapac-ethyl application reduced N removal by 13.2% on average. Nutrient removal via mowing is the primary factor which drives N fertilization requirements (McCarty, 2005). Relative reductions in N fertilizer were calculated by subtracting N removal from a select fertilizer rate treated not treated with TE from the next highest N rate treated with TE, divided by the difference of the higher and lower fertilizer rates not treated with TE. Nitrogen removal was decreased by 33 to 52% based on the relative differences presented in Table 3.5 for the 10 kg ha^{-1} and 20 kg ha^{-1} N when TE, respectively. Therefore N fertilization requirements would be reduced by a similar magnitude.

Color and Visual Quality

Nitrogen, date, and date x N interaction significantly affected visual quality and color index in all years (Table 3.3 and 3.4). Color index and visual quality ratings increased with N fertilizer application rate (Table 3.5). The tri-weekly, 0.05 kg a.i. ha^{-1} application rate TE applications did not affect turfgrass visual quality or color index during year one (Table 3.3). However, when TE was applied every 200 GDD at 0.10 kg a.i. ha^{-1} in 2009 and 2010 both color index and visual quality was statically enhanced (Table 3.4 and Figure 3.2). Average color index and visual quality increased from 6.9 to 7.4 and 242 to 253 with TE application in years two and three. Trinexapac-ethyl enhanced color index and visual quality within each fertilizer treatment although not to the same level as doubling N rate without applying TE (Table 3.5). On a relative basis, as previously described in the N removal section, addition of TE enhanced color index to a similar extent as increasing N rate by 30-35% and visual quality by 40-50% based on Table 3.5.

The interaction of TE and data is the result of delayed quality and color enhancement following initial TE application in the spring of each year (Figure 3.2). This effect has been was reported by McCullough et al. (2006a) and chapter two of this thesis. The year effect was very significant for color and quality and is likely due to truncated data collection in year three.

Visual quality and color index enhancements only occurred during years two and three when clipping yield was suppressed during the entire growing season. In year one, relative clipping yields fluctuated and resulted in no significant visual quality or color index enhancement. The change in TE application rate is a confounding factor because TE application rate directly influences turfgrass color (Stier et al., 1999). Research presented in chapter two also reported increased turfgrass color and quality at the 0.10 kg a.i. ha^{-1} rate in contrast to the 0.05 kg a.i. ha^{-1} rate and re-applied every 200 GDD. Turfgrass visual quality and color index did not occur when TE was applied at the four week re-application frequency regardless of application rate in chapter two. Based upon these findings, it is likely that sustained growth suppression is vital for sustained color and visual quality enhancement.

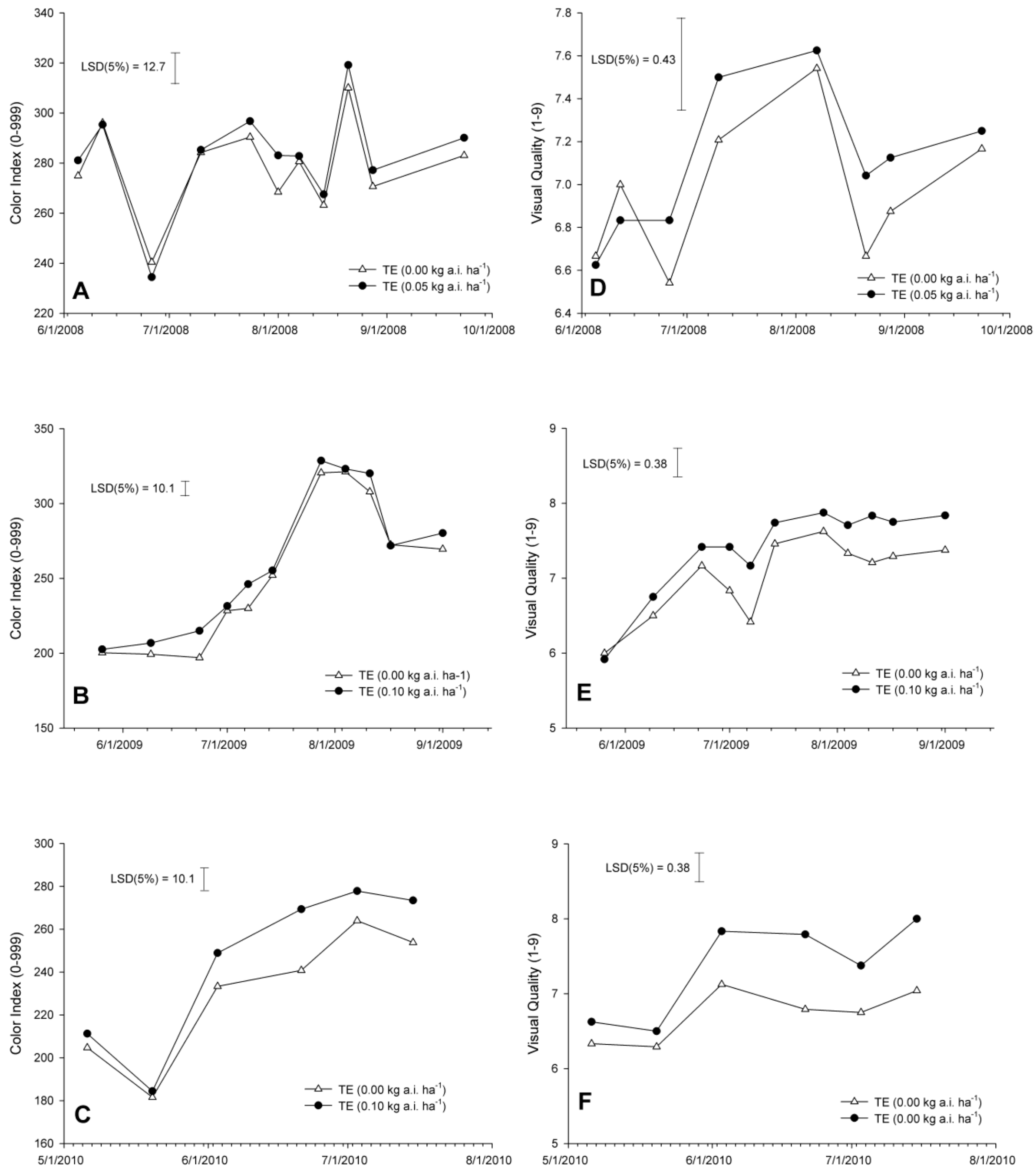

Figure 3.2. The effect of trinexapac-ethyl (TE) on color index and visual quality during 2008 (A and D), 2009 (B and E), and 2010 (C and F). TE was applied every three weeks at 0.05 kg a.i. ha^{-1} in 2008. During 2009 and 2010, TE was applied every 200 GDD at the rate of 0.10 kg a.i. ha^{-1}. GDD was the summation of mean daily air temperature, base 0°C, after TE application. After 200 GDD, TE was re-applied and the model was reset to zero.

CONCLUSIONS

Re-application of TE every 200 GDD can have profound implications on the nitrogen requirements of creeping bentgrass putting greens. Trinexapac-ethyl reduced putting green clipping yield by 16% and N removal via mowing by 13% regardless of fertilizer rate, which is similar in magnitude as reducing N rate by 30-50%. Trinexapac-ethyl re-applied every 200 GDD enhanced turfgrass visual quality and color index to a similar extent as increasing nitrogen by 30-50%. Therefore, application of TE every 200 GDD would allow N fertilizer rates to be reduced by 30 to 50% without having a negative impact on turfgrass visual quality or color. Furthermore, reducing nitrogen application rates in conjunction with TE application would considerable reduce clipping yield and may enhance ball roll distances.

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