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ANTHRACNOSE OF ANNUAL BLUEGRASS PUTTING GREEN TURF INFLUENCED BY TRINEXAPAC-ETHYL APPLICATION INTERVAL AND RATE

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ABSTRACT

Anthracnose (*Colletotrichum cereale* sensu lato Crouch, Clarke, and Hillman [formerly *C. graminicola* (Ces.) G.W. Wils.]) incidence and severity of annual bluegrass [*Poa annua* L. f. *reptans* (Hausskn) T. Koyama] putting greens has become increasingly devastating over the past 15 years. The effect of trinexapac-ethyl (TE) application interval (14 and 7 d) and rate (none, 0.04, 0.05 and 0.08 kg a.i. ha^{-1}) on anthracnose severity was assessed on annual bluegrass mowed at 3.2 mm from 2005 to 2007. Trinexapac-ethyl did not enhance disease severity regardless of application rate or interval, and TE had no or little effect on the disease in 2005 and 2007 while disease severity was reduced by TE in 2006. A reduction of 11 to 27% disease severity was observed in TE treatments when compared to untreated turf during 2006. Specifically, a shorter application interval (7 vs. 14 d) and greater TE rate (0.05 vs. 0.08 kg a.i. ha^{-1}) resulted in less anthracnose in 2006 when disease pressure was high. Disease severity declined linearly with increasing TE rate when applied every 7 d during 2006. Trinexapac-ethyl treatment increased seedheads 8 to 21% compared to untreated turf during the 3-yr trial. Trinexapac-ethyl applied every 7 d at 0.08 kg a.i. ha^{-1} initially reduced turf quality due to moderate phytotoxicity and increased seedheads compared to the same rate applied every 14 d early in the season during 2006 and 2007. However, TE treatments improved turf quality once seedheads subsided and disease severity increased later on in 2005 and 2006.

Abbreviations: ABG, annual bluegrass; N, nitrogen; TE, trinexapac-ethyl.

Keywords: plant growth regulator, seedhead, turf quality

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INTRODUCTION

Anthracnose is a destructive disease of turfgrasses, caused by the fungus *Colletotrichum cereale* Manns sensu lato Crouch, Clarke, and Hillman [formerly *C. graminicola* (Ces.) G.W. Wils.], and is particularly severe on ABG [*Poa annua* L. f. *reptans* (Hausskn) T. Koyama] throughout the United States, Canada, Western Europe, (Smiley et al., 2005; Smith et al., 1989) and Australia (Peart, 2007). The disease may exist as a foliar blight during high summer temperatures, or a basal rot which may occur any time of year. Symptoms initiate as small (6 to 12 mm) zones of chlorotic turf. Infested tillers (basal rot) are easily removed revealing a necrotic, water-soaked or black rot of tissue concealed beneath the outer leaf sheaths (Smiley et al., 2005). Melanized setae and acervuli develop on leaf blades and sheaths. The prevalence of anthracnose epiphytotics on golf course putting greens has increased over the past 15 years (Dernoeden, 2002; Landschoot and Hoyland, 1995; Mann and Newell, 2005; Wong and Midland, 2004). Factors which predispose turf to this disease are the focus of ongoing research (Murphy et al., 2008); because modern management practices intended to increase ball roll distance on putting greens are thought to intensify anthracnose severity by enhancing plant stress (Vermeulen, 2003; Zontek, 2004). Moreover, resistance of the fungus to a number of fungicide classes previously known to reduce anthracnose has been demonstrated (Avila-Adame et al., 2003; Crouch et al., 2005; Wong and Midland, 2007; Wong et al., 2007) further complicating efforts to control this disease.

Trinexapac-ethyl [4-(cyclopropyl-α-hydroxy-methylene)-3,5-di-oxocyclohexanecarboxylic acid ethylester] use on putting green turf has become commonplace within the past 15 yr ((Danneberger, 2003; Stewart et al., 2008). It is routinely applied throughout the season to improve vigor and playability of putting greens by reducing vertical shoot growth while increasing stand density and uniformity (Ervin and Koski, 1998; McCullough et al., 2005). However, the effect of TE on turfgrass diseases is not well understood.

Trinexapac-ethyl has been associated with reduced dollar spot (caused by *Sclerotinia homoeocarpa* F.T. Bennett) incidence in creeping bentgrass (*Agrostis stolonifera* L.); it was postulated that increased superoxide dismutase activity (Zhang and Schmidt, 2000) and elevated levels of total non-structural carbohydrates (Golembiewski and Danneberger, 1998) improved turf resistance to infection. Alternatively, other studies concluded that TE had no effect on dollar spot incidence (Burpee et al., 1996; Fidanza et al., 2006; Stewart et al., 2008) or brown patch (caused by *Rhizoctonia solani* Kuhn) (Burpee, 1998). Furthermore, Stewart et al. (2008) reported that curative applications of fungicides with TE delayed turf recovery from dollar spot damage compared to fungicides alone.

Trinexapac-ethyl applied every 14 d at 0.05 kg a.i. ha^{-1} occasionally reduced anthracnose severity of an ABG putting green in a one year study (Crouch et al., 2003); whereas the growth regulator applied every 28 d at the same rate to creeping bentgrass in another one year study had no effect on this disease (Vincelli and Doney, 1999). Trinexapac-ethyl applied at 0.05 kg a.i. ha^{-1} every 14 d in the absence of other growth regulators had little effect on anthracnose of ABG maintained at greens height over a three year period (Inguagiato et al., 2008). Some golf course superintendents use TE at rates greater than 0.05 kg a.i. ha^{-1} and/or at application intervals less than 14 d (Danneberger, 2006; Foy, 2008), but the impact of TE at higher rates or shorter intervals on anthracnose is currently unknown. Thus, the objective of this study was to evaluate a broader range of TE application intervals and rates for effects on anthracnose severity of ABG putting green turf.

MATERIALS AND METHODS

A three-year field study was initiated in 2005 on an ABG turf grown on a Nixon sandy loam (fine-loamy, mixed, mesic Typic Hapludaults) with a pH of 5.5 in North Brunswick, NJ. A monostand of ABG was established in the autumn of 2003 from seed indigenous to the site and ABG introduced in 1998 from Plainfield Country Club, Plainfield, NJ (Samaranayake et al., 2008). The previous mixed species turf [creeping bentgrass, velvet bentgrass (*A. canina* L.) and ABG] was eliminated from the experimental site with glyphosate [N-(phosphonomethyl) glycine] at 4.5 kg a.i. ha^{-1} on 10 Sep 2003. Thatch was removed and a seedbed was prepared by verticutting (6.4-mm depth) (model 544837, Commercial Grounds Care, Inc. Johnson Creek, WI) the site four times from 29 Aug to 6 Nov 2003. An ABG turf developed from the indigenous ABG seed, and a 3.2 mm cutting height was established by May 2004. The trial was inoculated (2 Aug 2004) with *C. cereale* isolate HFIIA (previously obtained from ABG at the Horticultural Research Farm II, North Brunswick, NJ) at 50,000 conidia mL^{-1} using the inoculum production and field inoculation procedure described by Inguagiato et al. (2008).

Field Maintenance.

Turf was mowed 10 to 14 times wk^{-1} with a triplex putting green mower (models 3000-04350 and 3150-04357, Toro Co., Bloomington, MN) bench set at 3.2 mm to simulate practices commonly utilized on golf course putting greens. Nitrogen was applied as necessary to sustain turf vigor and encourage recovery from disease damage incurred the preceding year to the field as water soluble sources totaling 120 kg ha^{-1} in 2005, 147 kg ha^{-1} in 2006 and 196 kg ha^{-1} in 2007. Nitrogen was annually distributed in 15 to 18 applications during 2005, 2006 and 2007 at: 53.8, 85.5 and 53.8 kg ha^{-1} from March to May; 44.0, 48.9 and 44.0 kg ha^{-1} from June to Aug; and 22.0, 34.2 and 97.7 kg ha^{-1} from Sep to Oct, respectively. Phosphorous and potassium were applied based on soil test results at 18.8 and 35.4 kg ha^{-1} in 2005, 22.9 and 45.6 kg ha^{-1} in 2006 and 11.8 and 34.3 kg ha^{-1} in 2007, respectively. The trial was topdressed at 88.7 cm^3 m^{-2} with silica sand (sub-angular, medium size) every 14 d from May to Sep each year. Sand was incorporated with a cocoa mat drag (Ace Equipment and Supply Co., Henderson, CO). Irrigation was applied to avoid drought stress yet maintain relatively dry soil conditions and to wash-in fertilizer. Dollar spot was preventatively controlled every 14 d during Jun and Jul 2005, May through Jul 2006, and May through Aug 2007 with vinclozolin [3-(3, 5-dichlorophenyl)-5-ethenyl-5-methyl-2, 4-oxazolidinedione] at 1.5 to 2.0 kg a.i. ha^{-1} or boscalid {3-pyridinecarboxamide, 2-chloro-N-[4'-chloro(1,1'-biphenyl)-2-yl]} at 0.4 to 0.6 kg a.i. ha^{-1}. Flutolanil {N-[3-(1-methylethoxy) phenyl]-2-[trifluoromethyl] benzamide} applied at 3.2 to 7.7 kg a.i. ha^{-1} was used to suppress brown patch every 14 d during Jun and Jul 2005 and 2006, and May through Aug 2007. Algae was controlled as necessary with mancozeb (coordination of Mn^{2+}, Zn^{2+} and ethylene bisdithiocarbamate) at 9.5 to 21.4 kg a.i. ha^{-1} in Jul and Aug 2005; and Jun and Jul 2007. These fungicides were previously determined not to be efficacious against anthracnose on ABG putting green turf (Towers et al., 2002). Annual bluegrass weevil [*Listronotus maculicollis* (Kirby)] was controlled with applications of bendiocarb (2,2-dimethyl-1,3-benzodioxol-4-yl methylcarbamate) at 2.3 kg a.i. ha^{-1} on 12 May 2005; bifenthrin {[2-methyl(1,1'-biphenyl)-3-yl]methyl 3-[2-chloro-3,3,3-trifluoro-1-propenyl]-2,2-dimethylcyclopropanecarboxylate} at 0.13 kg a.i. ha^{-1} on 27 Jun 2005, 2 May 2006 and 3 May and 19 Jun 2007; and trichlorfon [dimethyl(2,2,2-trichloro-1-hydroxyethyl) phosphonate] at 8.5 kg a.i. ha^{-1} on 14 Jul 2005. Anthracnose development was arrested at the conclusion of each study year to allow turf recovery during the autumn, winter and spring months; chlorothalonil (tetrachloroisophthalonitrile) was applied at 13.1 kg a.i. ha^{-1} on 18 Aug., 7, 18 Sep and 2 Oct 2005 and at 17.9 kg ha^{-1} on 26 Oct 2006. Chlorothalonil was also applied at 13.9 and 15.7 kg ha^{-1} on 14 Jul and 4 Sep 2006 to slow disease progress and prevent excessive turf loss.

Treatment Design.

The trial contained six treatments arranged in a randomized complete block design with four replications. Treatments included a control (untreated) and TE applied every 7 d at 0.04, 0.05 and 0.08 kg a.i. ha^{-1} or every 14 d at 0.05 and 0.08 kg a.i. ha^{-1}. Trinexapac-ethyl applications were made from 6 Apr through 27 Jul 2005, 31 Mar though 13 Sep 2006 and 28 Mar through 22 Aug 2007. Trinexapac-ethyl was applied with an operator propelled spray boom outfitted with flat-fan VS8003 nozzles (Spray Systems Co., Wheaton, IL) calibrated to deliver 408 L ha^{-1} at 269 kPa. Treatments were repeated in the same plot location each year.

Data Collection and Analysis.

Anthracnose basal rot severity was periodically assessed during Jun and Jul 2005, Jun through Sep 2006 and Jul through Aug 2007 as the percent turf area infested with *C. cereale* using a line-intercept grid count method described by Inguagiato et al. (2008). Seedhead expression was assessed from Apr or May through Jun each year by visually estimating the percent plot area containing seedheads. Turf quality was visually rated on a 1 to 9 scale (where 9 represented the best quality and 5 the minimum acceptable level) from May through Jul 2005, Apr through Aug 2006 and Apr through Jul 2007. Turf density, uniformity, color, phytotoxicity, seedhead expression and disease severity were components of turf quality.

All data were subjected to analysis of variance using the General Linear Model procedure in the Statistical Analysis System software v. 9.1.3 (SAS Institute Inc., Cary, NC, 2003). Single degree of freedom contrasts were used to test treatment effects (Steel et al., 1997). The treatment means associated with the contrast identifying a significant treatment interaction were separated by LSD ($p \leq 0.05$).

RESULTS AND DISCUSSION

Anthracnose Severity

Anthracnose basal rot developed throughout the study as a natural infestation on 7 Jun 2005, 18 Jun 2006 and 27 Jun 2007. The epiphytotic progressed slowly until 15 Jul 2005, when the disease resulted in 27 to 36% turf loss, but no discernable treatment differences were observed that year (Table 1). Disease developed very rapidly in 2006 with 55% of untreated turf being damaged by 3 Jul. Chlorothalonil was applied to lessen the severity of the epiphytotic on 14 Jul 2006, yet disease

Table 1. Anthracnose disease severity response to trinexapac-ethyl on annual bluegrass turf mowed at 3.2 mm in North Brunswick, NJ during 2005, 2006 and 2007.

Trinexapac-ethyl (TE)	Turf area infested												
	2005			2006					2007				
	14 June	2 July	15 July	23 June	3 July	21 July	16 Aug	12 Sept	3 July	12 July	27 July	4 Aug	16 Aug
	%												
untreated	3.7	7.9	35.1	17.4	54.9	73.4	73.2	44.9	7.1	11.4	23.9	35.7	54.5
0.04 kg a.i. ha^{-1}, 7 d	2.7	3.6	33.0	6.2	27.0	52.9	54.3	25.5	3.6	8.4	17.2	19.9	45.0
0.05 kg a.i. ha^{-1}, 14 d	3.9	7.2	33.7	7.8	33.0	61.8	58.8	33.4	8.2	13.6	22.0	31.5	53.6
0.05 kg a.i. ha^{-1}, 7 d	4.2	5.5	30.3	5.3	27.1	51.2	51.4	22.7	6.9	9.6	17.7	27.3	49.6
0.08 kg a.i. ha^{-1}, 14 d	3.8	4.9	36.0	9.6	31.9	50.5	48.8	26.4	4.9	7.6	20.9	34.9	52.1
0.08 kg a.i. ha^{-1}, 7 d	3.2	5.2	27.2	5.3	18.6	40.8	46.4	19.3	4.3	8.5	18.4	25.0	45.7
Planned *F*-tests	*P* > *F*												
Untreated *vs.* all TE†	NS#	NS	NS	***	***	***	***	***	NS	NS	NS	NS	NS
14 d *vs.* 7 d‡	NS	NS	NS	NS	*	*	NS	*	NS	NS	NS	NS	NS
0.05 *vs.* 0.08 kg a.i. ha^{-1}§	NS	NS	NS	NS	NS	**	*	NS	*	NS	NS	NS	NS
interval x rate interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
linear rate of TE,7 d¶	NS	NS	NS	***	***	***	***	***	NS	NS	NS	NS	NS

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
†Comparison of: untreated vs. 0.04 kg a.i. ha^{-1}, 7 d; 0.05 kg a.i. ha^{-1}, 14 d; 0.05 kg a.i. ha^{-1}, 7 d; 0.08 kg a.i. ha^{-1}, 14 d; and 0.08 kg a.i. ha^{-1}, 7 d.
‡Comparison of: 0.05 kg a.i. ha^{-1}, 14 d and 0.08 kg a.i. ha^{-1}, 14 d vs. 0.05 kg a.i. ha^{-1}, 7 d and 0.08 kg a.i. ha^{-1}, 7 d.
§Comparison of: 0.05 kg a.i. ha^{-1}, 14 d and 0.05 kg a.i. ha^{-1}, 7 d vs. 0.08 kg a.i. ha^{-1}, 14 d and 0.08 kg a.i. ha^{-1}, 7 d.
¶Coefficients to determine linear response of TE rates at 7 d interval on anthracnose: -17, -1, 3 and 15 for untreated, 0.04 kg a.i. ha^{-1}, 7 d; 0.05 kg a.i. ha^{-1}, 7 d and 0.08 kg a.i. ha^{-1}, 7 d, respectively.
#NS, not significant.

severity continued to increase through mid-Aug (46 to 73%) before declining in Sep. Disease severity increased gradually to 45 to 55% turf area infested by 16 Aug 2007.

Trinexapac-ethyl did not enhance disease severity regardless of application rate or interval throughout this three year study (Table 1). Rather, TE had no or little effect on disease severity in 2005 and 2007, while severity was reduced by TE on all rating dates in 2006. Trinexapac-ethyl applied every 7 or 14 d at 0.04 to 0.08 kg a.i. ha^{-1} reduced disease severity 11 to 27% compared to untreated turf throughout 2006. Shorter TE application interval (i.e., 7 d vs. 14 d) reduced disease severity 9 to 10% across both rates (0.05 and 0.08 kg a.i. ha^{-1}) in Jul and on 12 Sep 2006. Similarly, the greatest TE rate (0.08 kg a.i. ha^{-1}) reduced disease severity 8 to 11% compared to the 0.05 kg a.i. ha^{-1} rate across both application intervals during high disease pressure on 21 Jul and 16 Aug 2006, and 3% on 3 Jul 2007 when disease pressure was low. Application rate and interval did not interact to affect disease severity throughout the study. Disease severity declined linearly with increasing rate of TE (0, 0.04, 0.05 and 0.08 kg a.i. ha^{-1} applied every 7 d) during 2006, but there was no rate effect in 2005 and 2007 (Table 1).

Trinexapac-ethyl influenced anthracnose only one out of three years in this trial. Previous studies evaluating TE effects on anthracnose have reported occasional reductions (Crouch et al., 2003), little effect (Inguagiato et al., 2008) or no effect of TE on anthracnose (Vincelli and

Doney, 1999). Reduced disease severity on TE treated turf has been attributed to improved physiological and morphological characteristics of turf, which could enhance tolerance to anthracnose by improving plant vigor and minimizing stress (Inguagiato et al., 2008). However, the effect of TE on anthracnose is not well understood and it is possible that additional factors may be involved. Studies reporting disease reductions applied TE to ABG every 14 d at 0.05 kg a.i. ha^{-1} (Crouch et al., 2003; Inguagiato et al., 2008); whereas TE applied to creeping bentgrass every 28 d at the same rate had no effect on anthracnose (Vincelli and Doney, 1999). Therefore, turf species as well as application interval may affect anthracnose response to TE. In the current trial, TE applied every 7 and 14 d reduced anthracnose severity in 2006, a year when disease pressure was very high; decreasing the application interval to 7 d was occasionally more effective at reducing the disease.

Moderate N fertility is known to reduce anthracnose severity (Danneberger et al., 1983; Inguagiato et al., 2008). Inguagiato et al. (2008) noted that TE (applied every 14 d after spring mefluidide {*N*-[2,4-dimethyl-5-] (trifluoromethyl)sulfonyl]amino]phenyl]acetamide} application) produced the greatest reduction in anthracnose when turf was fertilized with N every 7 d at 4.9 kg ha^{-1}; whereas TE had lesser or no effect on similarly treated turf fertilized with N every 28 d. Nitrogen applications were generally

Table 2. Seedhead production response to trinexapacethyl on annual bluegrass turf mowed at 3.2 mm in North Brunswick, NJ during 2005, 2006 and 2007.

	Seedhead expression								
	2005			2006			2007		
Trinexapac-ethyl (TE)	13 May	4 June	14 June	24 May	9 June	19 June	24 Apr	22 May	19 June
	%								
untreated	78.8	46.3	20.0	52.5	29.3	27.5	22.5	53.8	28.8
0.04 kg a.i. ha^{-1}, 7 d	82.5	68.8	21.3	73.8	39.5	39.0	16.3	65.0	46.3
0.05 kg a.i. ha^{-1}, 14 d	81.3	55.0	20.0	60.0	33.3	32.3	22.5	60.0	45.0
0.05 kg a.i. ha^{-1}, 7 d	80.0	64.5	18.8	80.0	39.3	38.8	17.5	66.3	57.5
0.08 kg a.i. ha^{-1}, 14 d	83.8	57.5	20.0	62.5	34.3	30.5	18.8	61.3	40.0
0.08 kg a.i. ha^{-1}, 7 d	83.8	68.8	25.0	85.0	42.5	42.0	17.5	67.5	60.0
Planned *F*-tests	$P > F$								
untreated *vs.* all TE†	NS#	***	NS	***	***	***	NS	**	***
14 d *vs.* 7 d‡	NS	***	NS	***	***	***	NS	NS	***
0.05 *vs.* 0.08 kg a.i. ha^{-1}§	NS	NS	NS	NS	NS	NS	NS	NS	NS
interval x rate interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS
linear rate of TE,7 d¶	NS	***	NS	***	***	***	NS	**	***

*Significant at the 0.05 probability level.
**Significant at the 0.01 probability level.
***Significant at the 0.001 probability level.
†Comparison of: untreated vs. 0.04 kg a.i. ha^{-1}, 7 d; 0.05 kg a.i. ha^{-1}, 14 d; 0.05 kg a.i. ha^{-1}, 7 d; 0.08 kg a.i. ha^{-1}, 14 d; and 0.08 kg a.i. ha^{-1}, 7 d.
‡Comparison of: 0.05 kg a.i. ha^{-1}, 14 d and 0.08 kg a.i. ha^{-1}, 14 d vs. 0.05 kg a.i. ha^{-1}, 7 d and 0.08 kg a.i. ha^{-1}, 7 d.
§Comparison of: 0.05 kg a.i. ha^{-1}, 14 d and 0.05 kg a.i. ha^{-1}, 7 d vs. 0.08 kg a.i. ha^{-1}, 14 d and 0.08 kg a.i. ha^{-1}, 7 d.
¶Coefficients to determine linear response of TE rates at 7 d interval on seedhead expression: -17, -1, 3 and 15 for untreated, 0.04 kg a.i. ha^{-1}, 7 d; 0.05 kg a.i. ha^{-1}, 7 d and 0.08 kg a.i. ha^{-1}, 7 d, respectively.
#NS, not significant.

uniform in the current trial from June through August each year; however turf did receive an additional 31.7 kg N ha^{-1} from Mar through May 2006 than was applied during this period in 2005 and 2007. Fagerness et al. (2004) observed that ^{15}N allocation to roots and rhizomes was increased approximately 50%, and allocation to clippings was decreased approximately 25%, in TE treated bermudagrass (*Cynodon dactylon* X *C. transvaalensis* Burtt-Davey). Thus, turf treated with TE (31 Mar through 13 Sep 2006) may have increased allocation of N (provided by the increased N applied from Mar through May) to roots and possibly improved root number, function and viability. Since tolerance to summer stress has been associated with increased root depth and number (Bonos and Murphy, 1999; Xu and Huang, 2001), allocation of N to roots may have improved the vigor of ABG in our trial and reduced anthracnose severity during 2006.

Data from this three-year trial indicate that TE does not enhance anthracnose and can occasionally reduce disease severity even at increased application rates and shorter application intervals. Disease reductions observed only in 2006 suggest that TE applications combined with increased N fertility may result in more consistent reductions in disease severity; however this hypothesis needs to be validated.

Seedhead Expression

The average TE treatment effect increased seedheads 8 to 21% compared to untreated turf when differences occurred during the three-year trial (Table 2). More frequent TE applications (every 7 d) increased seedheads 7 to 21% compared to the 14-d interval (across 0.05 and 0.08 kg a.i. ha^{-1} rates). There was no difference in seedhead expression for TE applied at 0.05 versus 0.08 kg a.i. ha^{-1} across 7- and 14-d intervals throughout the study. However, the number of seedheads increased linearly throughout the study with increasing TE rate (0, 0.04, 0.05 and 0.08 kg a.i. ha^{-1}) applied every 7 d (Table 2). Previous studies have demonstrated that TE can reduce the initial expression of ABG seedheads compared to untreated turf (Fagerness and Penner, 1998; Inguagiato et al., 2008), but extend the period of seedhead expression (Inguagiato et al., 2008).this is probably due to TE reducing the elongation of the flowering culm (Borm and van den Berg, 2008), delaying the initial appearance of seedheads and limiting physical removal of seedheads with routine mowing.

Turf Quality

Turf quality was poor throughout most of the trial mainly due to phytotoxicity in Apr and May, retention of seedheads during May and Jun and disease from Jun to Aug (Table 3). The average TE treatment effect reduced turf quality in May 2005 and 2006 as well as Jun and Jul 2007 compared to untreated turf. This response was due in part to greater number of seedheads associated with TE applications in May 2006 and Jun 2007, and reduced density (component of turf quality ratings) once tillers senesced after seed set in Jul 2007.Growth regulation caused a moderate phytotoxic (i.e., yellow-gray turf color and reduced uniformity) effect in TE treated plots reducing turf quality in May 2005. However, turf quality was improved by TE treatment compared to untreated plots later in the season (21 Jul 2005, and 17 Jul and 25 Aug 2006) after seedhead production had ceased and turf density was declining due to disease. The improvement in turf quality of TE treated turf in Jul and Aug 2006 was also attributed to the reduction in disease severity during that period, but this effect was not observed in 2005 or 2007.

Table 3. Turf quality response to trinexapac-ethyl on annual bluegrass turf mowed at 3.2 mm in North Brunswick, NJ during 2005, 2006 and 2007.

	Turf quality											
	2005				2006					2007		
Trinexapac-ethyl (TE)	13 May	13 June	12 July	21 July	10 Apr	11 May	19 June	17 July	25 Aug	18 Apr	14 May	19 June
	1 – 9 (9 = best)											
untreated	4.0	5.0	4.5	2.3	4.0	5.0	4.8	1.3	3.0	2.5	4.5	6.3
0.04 kg a.i. ha^{-1}, 7 d	2.5	4.3	4.8	4.0	3.5	4.0	4.0	3.5	4.3	2.3	5.0	4.0
0.05 kg a.i. ha^{-1}, 14 d	4.0	5.5	4.8	3.5	3.5	4.8	5.0	2.5	3.8	2.0	5.5	5.0
0.05 kg a.i. ha^{-1}, 7 d	3.5	4.3	4.3	4.0	3.8	4.5	4.5	3.0	5.0	2.3	5.3	4.8
0.08 kg a.i. ha^{-1}, 14 d	3.5	4.3	5.0	4.0	3.8	4.5	4.0	3.5	5.0	2.8	4.8	5.3
0.08 kg a.i. ha^{-1}, 7 d	3.5	4.0	4.5	4.3	3.0	3.0	3.5	4.0	5.8	1.3	4.8	4.0
	$P > F$											
Planned *F*-tests												
untreated *vs.* all TE†	*	NS	NS	***	NS	**	NS	***	*	NS	NS	***
14 d *vs.* 7 d‡	NS#	*	NS	NS	NS	**	NS	NS	NS	NS	NS	**
0.05 *vs.* 0.08 kg a.i. ha^{-1}§	NS	*	NS	NS	NS	**	**	**	NS	NS	NS	NS
interval x rate interaction	NS	NS	NS	NS	*(0.7)††	*(0.7)	NS	NS	NS	*(1.2)	NS	NS
linear rate of TE,7 d¶	NS	*	NS	***	**	***	**	***	**	*	NS	***

*Significant at the 0.05 probability level.
**Significant at the 0.01 probability level.
***Significant at the 0.001 probability level.
†Comparison of: untreated vs. 0.04 kg a.i. ha^{-1}, 7 d; 0.05 kg a.i. ha^{-1}, 14 d; 0.05 kg a.i. ha^{-1}, 7 d; 0.08 kg a.i. ha^{-1}, 14 d; and 0.08 kg a.i. ha^{-1}, 7 d.
‡Comparison of: 0.05 kg a.i. ha^{-1}, 14 d and 0.08 kg a.i. ha^{-1}, 14 d vs. 0.05 kg a.i. ha^{-1}, 7 d and 0.08 kg a.i. ha^{-1}, 7 d.
§Comparison of: 0.05 kg a.i. ha^{-1}, 14 d and 0.05 kg a.i. ha^{-1}, 7 d vs. 0.08 kg a.i. ha^{-1}, 14 d and 0.08 kg a.i. ha^{-1}, 7 d.
¶Coefficients to determine linear response of TE rates at 7 d interval on turf quality: -17, -1, 3 and 15 for untreated, 0.04 kg a.i. ha^{-1}, 7 d; 0.05 kg a.i. ha^{-1}, 7 d and 0.08 kg a.i. ha^{-1}, 7 d, respectively.
#NS, not significant.
††Number in parenthesis represents Fisher's protected least significant difference ($\alpha = 0.05$) for comparing means involved in the interaction of TE interval (14 *vs.* 7 d) and rate (0.05 *vs.* 0.08 kg a.i. ha^{-1}).

The interaction between TE interval and rate in Apr and May 2006 and Apr 2007 indicated that TE applied every 7 d at 0.08 kg a.i. ha^{-1} reduced turf quality compared to the same rate applied at the 14-d interval; whereas application interval did not affect quality at 0.05 kg a.i. ha^{-1} (Table 3). Initially, the more frequent TE application at the higher rate caused phytotoxicity that reduced quality early in the season. Phytotoxicity was not a concern at the 7 d interval when TE was applied at 0.05 kg a.i. ha^{-1}.

Trinexapac-ethyl applied every 7 d reduced turf quality (Table 3) due to reduced turf uniformity (component of turf quality ratings) in Jun 2005 and prolonged seedhead retention in Jun 2007 (Table 2) compared to the 14-d interval across both rates (0.05 and 0.08 kg a.i. ha^{-1}). Greater TE rate (0.08 kg a.i. ha^{-1}) reduced quality across both application intervals due to reduced uniformity in Jun 2005 and 2006, although the greater rate eventually improved quality during high disease () pressure in Jul. Similarly, TE rate (0, 0.04, 0.05, and 0.08 kg a.i. ha^{-1}) at the 7 d interval produced a significant linear turf quality response on 10 of 13 observations. Increasing TE rate reduced turf quality due to phytotoxic effects in Apr 2006 and reduced turf color in Apr 2007 (data not shown); greater seedheads in May and Jun 2006 and Jun 2007 (Table 2); reduced uniformity in Jun 2005 and density in Jul 2007 following seed set. Conversely, increasing TE rate improved turf quality when disease severity was increasing in July 2005 and Jul and Aug 2006, but this effect was not observed in 2007.

CONCLUSION

Trinexapac-ethyl did not increase anthracnose severity in this trial. Thus, industry concerns that growth regulation with TE may enhance disease severity were not substantiated. In fact, TE occasionally (2006) reduced anthracnose severity, and beneficial effects were evident at relatively short application intervals (7 and 14 d) and increased rates (0.05 to 0.08 kg a.i. ha^{-1}). Turf managers should be cautious, however, of more aggressive TE application strategies (7 d interval and/or 0.8 kg a.i. ha^{-1}) during the spring because turf quality can be reduced by phytoxicity and a longer period of seedhead retention. Thus, management of ABG putting green turf with TE to improve turf quality and density, reduce clipping yield and improve playability should not be expected to antagonize a program of best management practices designed to control anthracnose on ABG. However, turf managers should not expect the use of TE to consistently reduce anthracnose severity.

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