Trinexapac-ethyl Restricts Shoot Growth and Prolongs Stand Density of ‘Meyer’ Zoysiagrass Fairway Under Shade

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Abstract. ‘Meyer’ zoysiagrass (Zoysia japonica Steud.) is a popular turfgrass species for transition zone golf course fairways and tees because it is generally winter hardy while providing an excellent playing surface with minimal chemical and irrigation inputs. However, its functionality declines readily on many of the shaded areas on these courses. Reduced irradiance causes excessive shoot elongation, reduced tillering, and weak plants that are poorly suited to tolerate or recover from traffic and divoting. Trinexapac-ethyl (TE) effectively reduces gibberellic acid (GA) biosynthesis and subsequent shoot cell elongation. The objective of this study was to determine if monthly applications of TE would reduce shoot elongation of ‘Meyer’ zoysiagrass and improve stand persistence under two levels of shade. Shade structures were constructed in the field that continuously restricted 77% and 89% irradiance. A mature stand of ‘Meyer’ was treated with all combinations of three levels of shade (0%, 77%, and 89%) and three levels of monthly TE application [0, 48 g·ha⁻¹ a.i. (0.5×), and 96 g·ha⁻¹ a.i. (1×)] in 1998 and 1999. In full sun, the 0.5× rate reduced clipping production by 17% to 20% over a four-week period and the 1× rate by 30% to 37%. Monthly application of TE at the 1× rate increased ‘Meyer’ tiller density in full sun and under 77% shade. Both rates of TE consistently reduced shoot growth under shade relative to the shaded control. Only the monthly applications at the 1× rate consistently delayed loss of quality under 77% shade. The zoysiagrass persisted very poorly under 89% shade whether treated or not with TE and plots were mostly dead at the end of the experiment. Our results indicate TE can be an effective management practice to increase ‘Meyer’ zoysiagrass persistence in shaded environments. Chemical name used: 4-cyclopropyl-α-hydroxy-methylene-3,5-dioxo-cyclohexanecarboxylic acid ethyl ester (trinexapac-ethyl)

Materials and Methods

This study was conducted on a mature stand of ‘Meyer’ zoysiagrass managed as a fairway at the Univ. of Missouri Turfgrass Research Center. The experimental area was irrigated once a week to replace 100% of estimated evapotranspiration and supplied with N at 49 kg·ha⁻¹ from urea in June and August of each year. The experimental ‘Meyer’ fairway had been in place at least 15 years over a Mexico silt loam (fine, montmorillonitic, mesic Mollic Endoaqualfs) with a pH of 6.5, organic matter of 4.9%, 92 kg·ha⁻¹ P, and 442 kg·ha⁻¹ K. The study consisted of two factors and four replications arranged in randomized complete blocks. The two factors were shade level and TE rate. Shade levels were: 0% shade, 73% shade cloth, and 92% shade cloth (Stumpy Greenhouse Manufacturing, Kansas City, Mo.). These shade levels were selected based on two factors. First, previous research by Qian and Engelke, indicated that Zoysia matrella ‘Diamond’ persisted under 73% shade without TE-treatment and up to 88% shade when treated monthly with TE. Second, yield measurements made on shaded and thinning ‘Meyer’ zoysiagrass fairways on golf courses in the Saint Louis area indicated that many of these fairways were in 90% shade for large portions of the day (Ervin, unpublished data). For the purposes of this study, the 73% treat-
ment was considered a moderately-heavy shade level, while the 92% was considered heavy shade.

Trinexapac-ethyl rates were: 0, 48 g·ha\(^{-1}\) a.i. (0.5\(\times\)rate), and 96 g·ha\(^{-1}\) a.i. (1\(\times\)rate). The 36 experimental units (4 \(\times\) 3 \(\times\) 3) were 2.1 m \(\times\) 1.5 m each, separated by a 1.5 m border. Shade cloths were mounted on copper pipe frames and supported 76 cm above the turf canopy. The shade cloth was draped on all sides down to 15 cm above the turf border. Shade cloths were mounted on cop-

LI-COR, Lincoln, Nebr.) from 1100 to 1400 HR quantum radiometer (model LI-190SA; Penner, 1998; Wiecko, 1997).

To determine clipping yield, a 0.6-m\(^2\) swath was cut weekly with a standard reel-type greens-mower at 16 mm, clippings were collected, dried for 24 h at 70°C, and weighed. Weekly clipping weight data are presented, in g·m\(^{-2}\), as the deviation from that of the full-sun control. Lines connecting data points do not represent actual or mathematically predicted data. These artificially smoothed lines have merely been added by the computer software (SigmaPlot 2000; SPSS, Chicago) so as to provide the reader with a sense of week to week clipping yield dynamics. Shade structures were removed once a week for 2 to 8 weeks after initial treatment (WAIT) from Aug. to Oct. 1998, peaking at 2 weeks after shade was imposed (Fig. 3 and 4).

**Results and Discussion**

In full sun conditions, the 1\(\times\)-rate of TE reduced clipping dry weight at 1, 2, 4, 5, 7, and 8 weeks after initial treatment (WAIT) from Aug. to Oct. 1998 (Fig. 1). Overall during this period, clippings were reduced by an average of 37%. As expected, the 0.5\(\times\)rate did not have as strong an effect as the 1\(\times\)-rate, reducing clippings at 1, 7, and 8 WAIT. Average reduction over this period was 17%. Similar results were found from June to Aug. 1999, where the 1\(\times\)-rate reduced clippings at 6, 7, 8, 9, 10, and 11 WAIT and the 0.5\(\times\)-rate at 6, 7, and 10 WAIT (Fig. 2). As has been reported for other turfgrass species, largest growth suppression generally occurs 2 to 3 weeks after each TE treatment (Ervin and Koski, 1998, 2001; Fagemness and Penner, 1998; Wiecko, 1997).

Under continuous 77% and 89% shade, ‘Meyer’ that was not treated with TE exhibited a large flush of shoot growth relative to the full sun control from Aug. to Oct. 1998, peaking at 2 weeks after shade was imposed. Qian and Engelke (1999) reported a light compensation point of 270 \(\mu\)mol·m\(^{-2}\)·s\(^{-1}\) for Zoysia matrella grown under 86% shade. If this value is representative of the light compensation point for Zoysia japonica, we would predict that under continuous clear sky conditions the 77% plots would be able to maintain a positive energy balance, while the 89% plots would not.

Analysis of variance was conducted on turf quality, clipping dry weight, and tiller number data for this standard 3 \(\times\) 3 factorial with the Michigan State Statistical Program v. 2.10 (MSTAT-C, 1993). Treatment means were separated using Fisher’s protected least significant difference (LSD).

Average photon flux densities during clear-sky conditions (in \(\mu\)mol·m\(^{-2}\)·s\(^{-1}\)) were 1634 on unshaded plots, 371 under 73% shade cloth, and 176 under 92% shade cloth. These values correspond to 0% shade, 77% shade, and 89% shade, respectively and will be used to designate the shade levels in this study. Quan and

[HORTScience, Vol. 37(3), June 2002]
Clipping production remained enhanced from 2 to 6 WAIT under 77% shade and from 1 to 4 WAIT under 89% shade. This expected response was most likely due to increased endogenous GA, levels in reduced light, as has been demonstrated recently for Kentucky bluegrass (Tan and Qian, 2000). Growth enhancement under 77% and 89% shade and no TE subsided at 7 WAIT, perhaps indicating a point where energy reserves had been largely depleted.

Trinexapac-ethyl significantly reduced shoot growth at the 1×-rate from 2 to 8 WAIT and 1 to 5 WAIT under 77% and 89% shade, respectively in 1998 (Figs. 3 and 4). Shoot growth of the TE-treated zoysia under 77% and 89% shade was less than or equal to the full sun control for the entire 8-week period. Thus, much energy-consuming shoot growth was eliminated by the use of TE on shaded ‘Meyer’ zoysiagrass.

From 1 to 4 WAIT in 1999 (28 May to 24 June), clipping production responses were similar to those reported during 1998 (data not shown). For example, in full sun, the 1×TE rate reduced clipping dry weight by an average of 30%, while under 77% shade, clipping production was increased by 20% (no TE) or unchanged (1×TE). Compared to the 1998 data where shade treatment without TE increased growth for up to 6 WAIT, growth enhancement only persisted for 4 WAIT in 1999. These results are most likely an indication of the cumulative energy depleting effects of shade treatment and traffic. This energy depletion supposition is supported by data from 5 to 12 WAIT in 1999, where ‘Meyer’ clipping production was reduced by similar amounts relative to the full sun control under both levels of shade whether treated with TE or not (Figs. 5 and 6). Both the 1998 and 1999 clipping production data indicate that untreated ‘Meyer’ zoysiagrass under 77% or greater shade begins to have a negative energy balance after continuous shade for eight weeks or longer. The shaded, TE-treated plants may be using energy faster than they can replace under this situation. However, because less energy was expended on shoot growth during the first eight weeks of shade, the duration of adequate stand persistence should be increased. The visual quality and tiller density data support this supposition.

Trinexapac-ethyl had no effect on the visual quality of ‘Meyer’ in full sun conditions over the course of the study (Table 1). About 8 weeks of shade treatment, however, reduced ‘Meyer’ quality significantly (9 Oct. 1998). Two applications of TE over this period, on both 77% and 89% shade plots, served to partially alleviate these quality reductions, especially the 1×-rate. By 18 June 1999, following 7 weeks of shade and 3 WAIT, greater quality was maintained at 77% shade due to the 1×-rate of TE. For the remainder of the study, only the 1×-rate under 77% shade retained higher quality relative to the other shaded treatments.

Tiller density counts at the beginning of the study indicated no differences (Table 2). A second assessment, on 2 June 1999, again indicated no clear differences. However, the final assessment on 9 Aug., indicated clear...
more resulted in lower shoot growth relative to six weeks. Shade treatment for six weeks or zoysiagrass clippings for approximately four in the greenhouse.

Zoysia matrella (1999) also reported greater maintenance of grass (Ervin and Koski, 2001). Qian and Engelke (1997) also reported greater maintenance of 'Meyer' tiller density following mul-

Table 1. Visual quality response of 'Meyer' zoysiagrass to shade and trinexapac-ethyl.

| Treatment | 15 Aug. 98 | 09 Oct. 98 | 18 June 99 | 18 July 99 | 23 Aug. 99 |
|-----------|------------|------------|------------|------------|------------|
| No shade + no TE | 7.5 | 7.5 | 6.9 a | 6.0 a | 6.3 a |
| No shade + 0.5x TE | 7.5 | 7.5 a | 6.9 a | 5.6 a | 6.4 a |
| No shade + 1x TE | 7.5 | 7.4 a | 6.8 a | 6.3 a | 6.0 a |
| 77% shade + no TE | 7.5 | 7.1 de | 4.9 c | 3.3 c | 1.9 c |
| 77% shade + 0.5x TE | 7.5 | 6.3 bc | 5.1 b | 4.5 b | 3.5 b |
| 77% shade + 1x TE | 7.5 | 6.3 bc | 5.1 b | 4.5 b | 3.5 b |
| 89% shade + no TE | 7.5 | 4.3 e | 4.5 c | 1.6 e | 1.0 d |
| 89% shade + 0.5x TE | 7.5 | 5.6 cd | 5.0 bc | 1.9 de | 1.0 d |
| 89% shade + 1x TE | 7.5 | 6.4 b | 5.3 bc | 2.5 d | 1.3 d |

LSD0.05 NS NS 36.1 NS

Table 2. Tiller density response of 'Meyer' zoysiagrass to shade and trinexapac-ethyl.

| Treatment | 17 Aug. 1998 | 2 June 1999 | 9 Aug. 1999 |
|-----------|--------------|-------------|-------------|
| No shade + no TE | 204.8 | 227.6 | 301.0 b |
| No shade + 0.5x TE | 222.5 | 256.4 | 270.3 b |
| No shade + 1x TE | 244.0 | 232.8 | 338.0 a |
| 77% shade + no TE | 251.6 | 231.4 | 45.4 d |
| 77% shade + 0.5x TE | 231.4 | 203.4 | 63.6 cd |
| 77% shade + 1x TE | 211.3 | 207.9 | 89.3 cd |
| 89% shade + no TE | 241.1 | 222.0 | 3.3 e |
| 89% shade + 0.5x TE | 232.9 | 249.6 | 9.3 e |
| 89% shade + 1x TE | 211.8 | 199.8 | 30.6 de |

LSD0.05 NS NS NS 36.1 NS

Nonsignificant.