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RESEARCH ARTICLE

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Growth responses of Kentucky bluegrass (*Poa pratensis* L.) to trinexapac-ethyl applied in spring and autumn

Abstract The practices with low clippings production to save time, money, or landfill space, were favored by turf managers. Understanding the responses of Kentucky bluegrass (*Poa pratensis* L.) to Trinexapac-ethyl (TE) would facilitate recommendations regarding its safe and effective use in Northern China. The objectives of this study are (1) to investigate the effects of TE on vertical growth, clipping yield, leaf width, and chlorophyll content of Kentucky bluegrass, and (2) to compare the seasonal application impacts of TE. Both spring and autumn experiment results demonstrated that Trinexapac-ethyl applied to Kentucky bluegrass, suppressed the vertical grass growth and significantly reduced the Kentucky bluegrass clippings production within a few weeks after initial treatment. Applied trinexapac-ethyl enhanced Kentucky bluegrass leaf width in both spring and autumn experimental periods. Discoloration on leaf tips was observed and lasted for four weeks when the same TE rate of 0.191 $mL \cdot m^{-2}$ was applied in early autumn. Darker leaves with higher chlorophyll content compared with non-TE-treatments appeared after the initial four weeks of the treatment in autumn and the treatment for the entire spring.

Keywords Kentucky bluegrass, trinexapac-ethyl, clipping yield, leaf width, chlorophyll content

1 Introduction

Kentucky bluegrass (*Poa pratensis* L.) is one of the most widely used cool-season turfgrass species for golf courses, sport fields, parks, public roadsides, and other commercial sites. There are two optimum growing periods for growing cool-season turfgrass in Northern China, which happens in spring and autumn. Its rapid vertical growth requires more frequent mowing and thereafter produces much clippings, which means its maintenance is costly. One approach that is commonly used in many countries for addressing these problems was the use of plant growth regulators (PGRs).

Ttrinexapac-ethyl (TE), a kind of plant growth regulator, was introduced for use in turf maintenance in 1991 (Waschke and Dipaola, 1995) and is a gibberellic acid (GA) inhibitor that suppresses laminar cell elongation by inhibiting the 3-β-hydroxylase conversion of gibberellic acid-20 to the physiologically-active GA1 (Adams et al., 1992). TE is widely used to enhance turfgrasses color and truf quality while suppressing their vegetative growth. Researches showed that TE reduced cool-season turfgrass' shoot growth (Johnson, 1993; Burpee et al., 1996; Daniels and Sugden, 1996; Ervin and Koski, 1998) but did not negatively affect its cool- or warm-season photosynthesis (Qian et al., 1998). Ervin and Koski (1998) reported that multiple applications of TE to greenhouse-grown perennial ryegrass increased the final tiller density. However, limited publications were available regarding turf growth responses to TE, and at present, no research on the seasonal impact of multiple TE application to turfgrass in Northern China has been reported.

The objectives of this study are (1) to investigate the effects of trinexapac-ethyl (TE) on the vertical growth, clipping yield, leaf width, and chlorophyll content of Kentucky bluegrass, and (2) to compare the seasonal application impacts of TE. Our results may provide some management recommendations for seasonal application patterns of TE in cool-season turfgrass species.

2 Materials and methods

The experiment was conducted in Turf Research Center of Agricultural University of Hebei, Baoding, China. The study was initiated in the spring of 2007 using a three-year-old stand of Kentucky bluegrass (established in pots in

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2004). The cultivar of Kentucky bluegrass was NuGlade. The soil in the growth pot (diameter: 28 cm, height: 30 cm) was composed of 57% sand, 14% peat and 29% organic fertilizer. The grass stand was fertilized monthly with $6\,g\cdot m^{-2}$ N, $3\,g\cdot m^{-2}$ P_2O_5 and $3\,g\cdot m^{-2}$ K_2O from April through October and was irrigated betimes. The stand was maintained throughout the growing season at a cutting height of 4.0 cm.

The initial application of Trinexapac-ethyl was on April 28, 2007 in spring, and the autumn application was on the September 1 of the same year. The TE application rate was $0.191\,mL\cdot m^{-2}$ in both seasons, which was determined by Liu (2006). Randomized complete block design with four replications was used in the experiment. For both spring and autumn experimental periods, the vertical height growth was evaluated weekly using the five-point sampling method since the day of TE application. The leaf width was determined by measuring 10 leaves in each pot with a micrometer.

Turfgrass was cut at the height of 4.0 cm every two weeks after TE application. The clippings that were collected in the 20-cm circle in the middle of each pot were oven dried at 105°C for 48 h and then weighed.

Chlorophyll content was determined on the second, fourth, sixth, and eighth week after initial treatment with spectrophotometry. $Ca = 13.95D665 - 6.88D649$, $Cb = 24.96D649 - 7.32D665$, where Ca and Cb are the contents of Chlorophyll a and Chlorophyll b, respectively, and, D649 and D665 are the extinction values of pigment solutions at 649 nm and 665 nm, respectively.

All data processing and statistical analysis were performed using Excel and data processing software (DPS).

3 Results and analysis

3.1 Vertical growth responses of Kentucky bluegrass to TE

The height of turf surely affects its lawn ornamental values. If the turf is too high, the lawn would appear disorderly, and the stem would be tender. A short and uniform turf surface would be attractive and durable.

Trinexapac-ethyl caused significant vertical growth reduction compared with the control treatment in both spring and autumn seasons (Fig. 1). This result showed that the application of TE could suppress turfgrass growth for six weeks after TE initial treatment. However, TE-treated turfgrass seemed to grow at the same speed during the following week and tended to grow higher than the control as the regulation wore off in the 8th week. This fact was particularly evident for those TE-treated in spring.

3.2 Effects of TE on clipping yield of Kentucky bluegrass

Kentucky bluegrass clippings were significantly reduced by applying trinexapac-ethyl at both seasons (Table 1). The maximum suppression occurred in the first four weeks of the TE treatment. In this experiment, TE could reduce biomass production by 46.32% during the first two weeks from April 28 to May 12, and by 48.52% within the second two weeks from May 13 to May 28. Clipping dry weight response to TE was affected by the application date, with a stronger response for spring application, and a relatively weaker response for autumn period. The clipping yield (Table 1) revealed that Kentucky bluegrass clippings were reduced by 23.86% during the first two weeks from September 1 to 14 and by 39.36% during the third and fourth week from September 15 to 29. The differences of clippings production between spring and autumn were most likely due to the rapid growth in spring. The dry weight of clipping collected after the initial six weeks after initial application showed similar trends for different seasonal treatments, which were in highly agreement to the results of Kentucky bluegrass height. The TE effects tends to be greater for the first six weeks, and the suppression effects on Kentucky bluegrass clipping production became less and approached that of controls near the end of the experiment. Grass growth for both spring and autumn TE-applications began to increase starting from the seventh week.

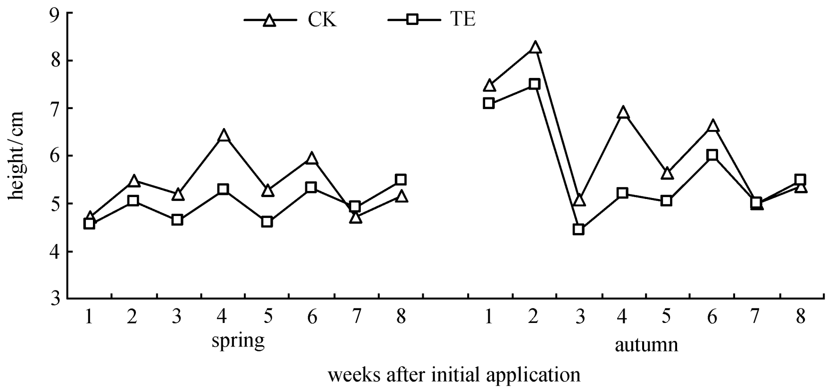

Fig. 1 Effects of trinexapac-ethyl on Kentucky bluegrass height

Table 1 Clippings dry weight after TE application ($g \cdot m^{-2}$)

TE treatment	weeks after initial application							
	spring				autumn			
	2	4	6	8	2	4	6	8
CK	50.99 a	29.12 a	27.42 a	38.89 b	48.12 a	35.16 a	34.27 a	22.03 a
TE	27.37 b	14.99 b	26.54 a	48.93 a	36.64 b	21.32 b	29.19 a	23.04 a

Note: Values followed by different letters within the same column are significantly different at 0.05 probability level.

3.3 Leaf width of Kentucky bluegrass after TE treatment

Our experimental results showed that the turf receiving the TE-treatment exhibited wider turfgrass leaves (Fig. 2) throughout the experimental periods in both seasons, and the effects lasted much longer than clippings production and plant height. Results in Fig. 2 shows the average leaf width four weeks after the initial treatment with TE treatment was 2.68 mm, however, 2.45 mm with non-TE treatment, with an increase rate of 9%. In the eighth week after the treatment, the leaf width was 2.72 mm for the TE treatment and 2.35 mm for non-TE treatment, with an increase rate of 16%. On September 25, the leaf width was 2.43 mm for TE treatment and 2.25 mm for non-TE treated control, with an increase rate of 8%. On October 9, the leaf width was 2.4 mm for TE treatment and increased by 11% compared with controls. The wider leaf turfgrass made the turf look more dense and stronger than the control treatments.

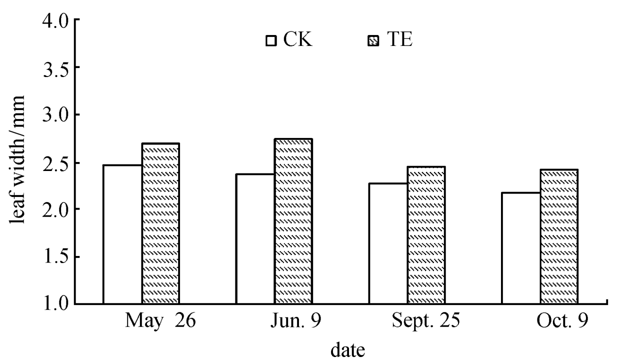

Fig. 2 Effects of trinexapac-ethyl on Kentucky bluegrass leaf width

3.4 Effects of TE on chlorophyll content of Kentucky bluegrass

In this experiment, the TE application date showed a different appearance between spring and autumn. Trinexapac-ethyl-treated turf had a higher chlorophyll content than the untreated controls (Fig. 3) for the spring treatment group and had better quality turf with darker green leaves and more dense turf compared with controls.

The determined data (Fig. 3) illustrated that there was an initial reduction in chlorophyll contents for autumn treatment group. The discoloration on leaf tips was observed during the first two to four weeks after TE autumn application, and the visual quality tended to decline. The results indicated that the TE-treated-and-potted turf attained darker leaves four weeks later and kept a much higher chlorophyll content for the following weeks even though TE application slightly reduced the visual quality of treated turf for the initial four weeks of the autumn treatment. One explanation for the initial negative effects resulting from the TE autumn application may be that Kentucky bluegrass as a cool-season turfgrass was undergoing the recovery from summer stress and was more sensitive to TE in early autumn. Lower TE-using rate or middle-autumn application scheme might be needed for diminishing the discolor appearance.

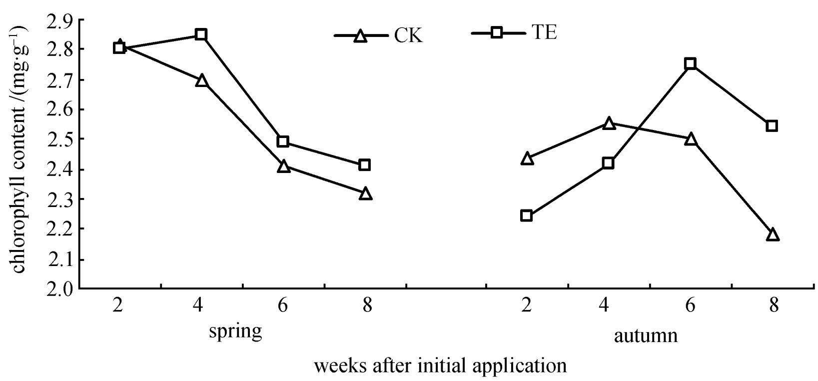

Fig. 3 Effects of trinexapac-ethyl on Kentucky bluegrass

4 Conclusions

Both spring and autumn experimental results demonstrated that trinexapac-ethyl applied to Kentucky bluegrass suppressed the vertical grass growth and significantly reduced the Kentucky bluegrass clippings production within a few weeks after the initial treatment, which means less mowing frequencies are required and lower maintenance cost is needed.

Trinexapac-ethyl application enhanced Kentucky bluegrass leaf width growth in both spring and autumn experimental periods. However, discoloration on the leaf tips was observed in the first four weeks after TE treatment when the same TE rate was applied in early autumn. The darker leaves with higher chlorophyll content compared with non-TE-treated controls appeared four weeks after treatment in autumn and in the entire spring.

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