Response of Creeping Bentgrass to Nitrogen and Ethephon

Patrick E. McCullough1
Department of Plant Biology and Pathology, Rutgers, The State University of New Jersey, New Brunswick, NJ 08901-8520

Haibo Liu2 and Lambert B. McCarty3
Department of Horticulture, Clemson University, Clemson, SC 29634-0375

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Abstract. Ethephon is an effective growth retardant for suppressing Poa annua (L.) seedheads in creeping bentgrass putting greens; however, ethylene induction may cause bentgrass leaf chlorosis, reduced rooting, and quality decline. Two greenhouse experiments investigated the effects of nitrogen (N) fertility and ethephon applications on ‘L-93’ creeping bentgrass over 9 weeks. Ethephon was applied at 0, 3.8, and 7.6 kg·ha–1 a.i. per 3 weeks and N was applied at 4 and 8 kg·ha–1 week–1. Ethephon applications linearly reduced bentgrass quality on every weekly observation. Increased N rate to 8 kg·ha–1 week–1 improved turf quality about 10% to 20% and 10% to 30% from ethephon applied at 3.8 and 7.6 kg·ha–1 per 3 weeks, respectively. Increased N rate to 8 kg·ha–1 week–1 enhanced shoot growth 30% but reduced root mass and length 12% and 11%, respectively. After 9 weeks, ethephon reduced root length by about 30% and root mass about 35% at both rates. From nine weekly samples, ethephon reduced dry clipping yield 10% and 16% at 3.8 and 7.6 kg·ha–1 per 3 weeks, respectively. From 2 to 9 weeks after initial treatments, ethephon linearly increased leaf water content. Increasing N fertility effectively reduced bentgrass leaf chlorosis from ethephon; however, repeat applications of ethephon and increased N may restrict bentgrass root growth. Chemical names used: [N(2-chloroethyl)phosphonic acid] (ethephon).

Creeping bentgrass (Agrostis stolonifera Huds.) with heavy Poa annua (L.) infestations requires intensive management to produce commercially acceptable putting green surfaces (Engel and Illinicki, 1969; McCarty et al., 2005a). Compared to creeping bentgrass, Poa annua has a lighter green color, coarser texture, and produces unsightly seedheads which may disrupt surface uniformity and decrease ball roll distances (Beard, 1973). Since selective herbicides for established Poa annua control are currently not available in creeping bentgrass putting greens, plant growth regulators (PGRs) are commonly applied to suppress its growth and seedhead formation.

Ethephon is a PGR currently used in the turf industry for Poa annua management in bentgrass golf greens. When reacted with water, ethephon diffuses to ethylene which inhibits growth by signaling damage, stress, or injury to plant cells (Taz and Zeiger, 2002). Ethylene release also delays flowering, selectively aborts flowers, and reduces stem elongation (Serek and Reid, 2000). Furthermore, changes in hormone balance favoring ethylene create a lower cytokinin ratio with less energy directed towards cell division required for seedhead emergence. With these unique properties, ethephon effectively arrests Poa annua seedhead formation in creeping bentgrass putting greens (Eggen et al., 1989; Gelertner and Stowell, 2001). However, leaf senescence and chlorophyll breakdown from ethylene induction may reduce bentgrass color and turf density, thus limiting the use of ethephon for putting green turf.

Routine nitrogen (N) fertility may significantly influence plant responses to ethephon applications. Nitrogen is the mineral nutrient required in greatest amounts by turfgrasses and produces unsightly seedheads which may be critical when applying this PGR. The objective of this experiment was to investigate growth responses of ‘L-93’ creeping bentgrass to ethephon and N fertility.

Materials and Methods

Nine week greenhouse experiments were conducted at the Clemson University Greenhouse Research Complex, Clemson, S.C., from December 2003 to February 2004 and from April to June 2004. Greenhouse day/night temperatures were set for about 26/20 °C. Due to reduced natural lighting during winter months, the experimental design was a randomized complete block with three replications of six polyvinylchloride containers per block (two N rates and three ethephon rates). Supplemental lighting was added for about 3 h·d–1 at 50 µmol·m–2·s–1. Blocks were rotated every three weeks and re-randomized within.

‘L-93’ creeping bentgrass plugs were collected from an experimental putting green located at the Turf Service Center, Clemson, established in August 2002. Turf plugs were washed free of soil and roots were cut to about 2.5 cm from the thatch layer. Plugs were then transplanted to polyvinyl chloride containers constructed approximately to United States Golf Association specifications (USGA Green Section Staff, 1993) to mimic field conditions. A 85 sand : 15 peat moss (by volume) rootzone mix consisting of 6% coarse sand (0.5 to 1.0 mm), 30% medium sand (0.25 to 0.5 mm), 48% fine sand (0.1 to 0.25 mm), and 16% very fine sand (<0.1 mm) was used. Containers had 40 cm depths with 177-mm2 surface areas and had drainage holes cut at about 6 mm diameters at the bottom. A starting fertilizer (9N–18P2O2–17K2O; Scott’s, Marysville, Ohio) was mixed into the soil at 48 kg·ha–1 N. The fertilizer also contained Ca, Mg, and S at 4%, 2%, and 7%, respectively.

Turf was established 3 weeks before initial ethephon treatments. Bentgrass was mowed at about 4 mm mowing height with automatic grass sheers (Black and Decker, Towson, Md.) and watered to field capacity 5 d·week–1. Ethephon (2L) was applied at 0, 3.8, and 7.6 kg·ha–1 a.i. per 3 weeks with a greenhouse spray chamber, Devries Manufacturing (Hollandale, Minn.) delivering 720 L·ha–1. Beginning five days after initial ethephon applications, ammonium nitrate (34N–0P2O5–0K2O) solution was applied at 4 and 8 kg·ha–1 N per week.

Bentgrass quality ratings were evaluated weekly on a 1 to 9 scale with 1 equal to completely dormant or brown turf and 9 equal to dark green, uniform turf. Clippings were harvested weekly, oven dried at 80 °C for 48 h, and then weighed. Before oven drying, fresh weight clipping yield was recorded and leaf water content estimated by the following formula: leaf water content = 1 – (dry weight clippings/fresh weight clippings).

Roots were harvested from the entire container after 9 weeks, oven-dried, and then weighed. Root length was determined by measuring the distance from where roots were no longer present in the soil profile to the top of the container. Data analyses were made using the analysis of variance with SAS General Linear Model procedure (SAS Institute, 1999). Orthogonal polynomial contrasts examined linear and quadratic relationships between plant response and level of ethephon. Study by treatment interactions did not occur for any parameters; therefore, the two studies were combined.

Results and Discussion

Bentgrass visual quality linearly decreased with ethephon rates on every weekly observation (Table 1). Similar reductions in turf quality have been observed in cool and warm
Table 1. Visual quality of ‘L-93’ creeping bentgrass treated with nitrogen and ethephon in two combined greenhouse experiments.

| N (kg·ha⁻¹·week⁻¹) | Ethephon (kg·ha⁻¹ per 3 weeks) | Visual quality(1–9) (WAIEP) | P value |
|---------------------|---------------------------------|-----------------------------|---------|
|                     | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 4                   | 0 | 7.3 | 7.1 | 6.7 | 6.5 | 6.8 | 6.9 | 7.2 | 6.9 | 7.3 |
|                     | 3.8 | 6.3 | 6.7 | 6.4 | 5.3 | 6.0 | 6.3 | 5.5 | 5.8 | 5.8 |
|                     | 7.6 | 5.4 | 6.2 | 6.2 | 4.3 | 4.8 | 5.5 | 4.5 | 5.0 | 5.1 |
| 8                   | 0 | 7.2 | 7.0 | 7.3 | 7.5 | 7.8 | 7.9 | 7.9 | 8.0 | 7.8 |
|                     | 3.8 | 6.5 | 6.9 | 6.9 | 6.3 | 6.7 | 7.0 | 6.5 | 7.1 | 6.9 |
|                     | 7.6 | 6.2 | 6.8 | 7.0 | 5.0 | 6.1 | 6.4 | 5.8 | 6.5 | 5.9 |

Source of variation

| N | Ethephon | Linear | Quadratic | N × ethephon |
|---|----------|--------|-----------|--------------|
| P value | 0.0105 | 0.0378 | 0.0005 | 0.0021 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0030 |

Table 2. Dry clipping yield for ‘L-93’ creeping bentgrass in two combined greenhouse experiments.

| Treatment  | Clipping yield (g·m⁻²) | P value |
|------------|------------------------|---------|
| N (kg·ha⁻¹·week⁻¹) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 4 | 0.75 | 0.97 |
| 0 | 0.94 |
| 3.8 | 0.85 |
| 7.6 | 0.79 |
| Source of variation | N | Ethephon | Linear | Quadratic | N × ethephon |
| P value | 0.0001 | 0.0172 | 0.0041 | NS | NS |

Ammonium nitrate (34-0-0) was the nitrogen source.

Table 3. Dry root mass and root length for ‘L-93’ creeping bentgrass after 9 weeks in two combined greenhouse experiments.

| N (kg·ha⁻¹·week⁻¹) | Ethephon (kg·ha⁻¹ per 3 weeks) | Dry root mass (g·m⁻²) | Root length (cm) | P value |
|---------------------|---------------------------------|----------------------|-----------------|---------|
| 4                   | 0 | 38 | 22 |
|                     | 3.8 | 26 | 18 |
|                     | 7.6 | 25 | 17 |
| 8                   | 0 | 36 | 22 |
|                     | 3.8 | 21 | 14 |
|                     | 7.6 | 23 | 13 |

Source of variation

| N | Ethephon | Linear | Quadratic | N × ethephon |
|---|----------|--------|-----------|--------------|
| P value | NS | 0.0013 | 0.0001 | 0.0290 | 0.0475 |

Leaf water content linearly increased with ethephon rates from week 2 to 9 (Table 4). Similarly, bentgrass fertilized with 8 kg·ha⁻¹ N per week had greater leaf water content than 4 kg·ha⁻¹ N per week, likely resulting from more actively growing tissue. Increased water content with ethephon applications contradicts dry clipping yield results; however, this may indicate a physiological response from ethephon use. Ethylene induction promotes lateral cell expansion (Taiz and Zeiger, 2002), thus higher water concentrations may accumulate in plant cells as a result. Consequently, increased leaf water content may create more succulent leaf tissue which may increase bentgrass susceptibility to injury and pathogen invasion.

Creeping bentgrass leaf morphological responses following ethephon applications may reduce leaf texture and putting green uniformity. Ethephon applications have shown to significantly reduce ball roll distances on a monostand creeping bentgrass putting green compared to untreated turf (McCullough et al., 2005). Effects of increased leaf water content on bentgrass leaf texture may explain reductions in putting green ball roll distances. Conversely, when Poa annua is the predominant species in a putting green, arresting seedhead production with ethephon may drastically improve ball roll distances and bentgrass leaf responses may not be a concern.

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| P value | NS | 0.0013 | 0.0001 | 0.0290 | 0.0475 |

Nitrogen source was 34–0–0 ammonium nitrate solution.

Clipping yield was pooled over nine weekly samples in both experiments.

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Roots were harvested from the entire container after 9 weeks.

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In another experiment with ethephon, Jiang and Fry (1998) noted the PGR increased perennial ryegrass quality under drought conditions. Ethephon, therefore, may effectively prepare turfgrasses for potentially stressful conditions, such as heat and drought stress. Further research is needed to address turfgrass physiological responses following ethephon applications under various environmental conditions.

In conclusion, applications of ethephon may be extremely phytotoxic to creeping bentgrass putting greens; however, routine N fertility may significantly influence bentgrass tolerances to ethephon. Although higher N rates reduce leaf chlorosis, repeat applications of ethephon and increased N have potential to restrict bentgrass root growth. These responses may limit the applicability of ethephon for creeping bentgrass putting greens.

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