in a similar PGR breakdown response under high temperatures, although PAC had a longer half-life in both species, and Kentucky bluegrass was regulated for a longer period than creeping bentgrass (Branham and Beasley 2007). Researchers at the University of Wisconsin-Madison built on this work by establishing growing-degree-day (GDD) application interval timings for TE and PAC applications to creeping bentgrass putting greens (Soldat 2011; Kreuser and Soldat 2012). This work helped to improve the consistency of suppression without over-applying PGRs, while avoiding the rebound phase following PGR breakdown. Plant growth regulator GDD models are calculated by determining the mean daily air temperature in degrees Celsius and adding this number to consecutive days until the threshold is reached. The base temperature used is 0 degrees Celsius. Current models developed for TE and PAC regulation of bentgrass putting greens require applications at 200 and 300 GDD, respectively.

The goal of this research was to establish a GDD application model for consistent season-long suppression of Kentucky bluegrass fairways with PAC. Knowing that Kentucky bluegrass is regulated for a longer duration than creeping bentgrass and fairway height turf can tolerate higher rates, the models used in this research have longer GDD application intervals and rates relevant for fairways. Note that our application rates in some instances exceed the label rate and was done so for experimental purposes.

Study Design

This study was carried out on a 75/25 mixed stand of Kentucky bluegrass and annual bluegrass maintained as a fairway at Tartan Park

Golf Course in Lake Elmo, MN during the 2013 growing season. The fairway was mown three days a week at 0.6 inches, and received irrigation as necessary to prevent drought stress. Treatments were applied with a CO_2 backpack sprayer calibrated to deliver 1 gallon per 1000ft^2 and irrigation or rainfall occurred within 24 hours of application. The treatment list is included in Table 1.

TABLE 1. Study Treatment List and Application Intervals

Treatment #	Product	Active ingredient	Rate (oz/ac)	Application interval
1	Trimmit 2SC	Paclobutrazol	8	400 GDD
2	Trimmit 2SC	Paclobutrazol	16	400 GDD
3	Trimmit 2SC	Paclobutrazol	24	400 GDD
4	Trimmit 2SC	Paclobutrazol	8	800 GDD
5	Trimmit 2SC	Paclobutrazol	16	800 GDD
6	Trimmit 2SC	Paclobutrazol	24	800 GDD
7	Trimmit 2SC	Paclobutrazol	24	June 3, July 30, Sept. 30
8	Primo Maxx	Trinexapac-ethyl	24	400 GDD
9	Untreated	N/A	N/A	N/A

For this study, GDD were determined by subtracting the base growing degree temperature (0° C) from the daily mean temperature (also in ° C). Growing degree days began accumulating after each application and the sum was reset to zero after each application was made. Initial applications were made on 3 June, 2013, with the last application applied on October 1st, 2013 (Table 1). Plots were 5 ft x 10 ft and arranged in a randomized complete block design with four replications.

Data collected weekly included clipping biomass, relative chlorophyll index and turf quality. Clipping biomass was collected using a Toro walk-behind mower (Greensmaster 1600 series, Toro, Bloomington,

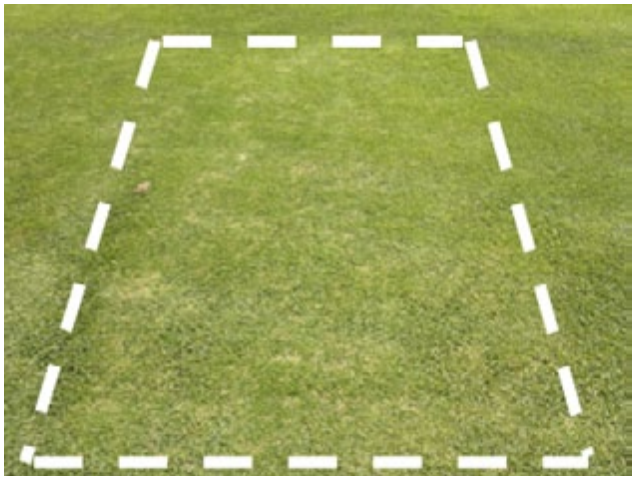
MN) making one pass down the middle of each plot following 24 h of growth. Post-harvest, clippings were dried in an oven set to 95 degrees Fahrenheit for at least 48 h before being weighed. Chlorophyll index was determined using the Field Scout CM1000 (Spectrum Technologies, Aurora, IL) by taking the average of nine random readings across each plot area. Turf quality was visually assessed on a 1-9 scale with 6 being minimally acceptable turf. Due to phytotoxicity after initial applications, phytotoxicity ratings were made for three consecutive weeks using 0-5 scale with 0 being no visible signs of phytotoxicity and 3 being the maximum acceptable. At the initial and last rating, a visual percent annual bluegrass per plot was made to determine if there was any reduction in the annual bluegrass population.

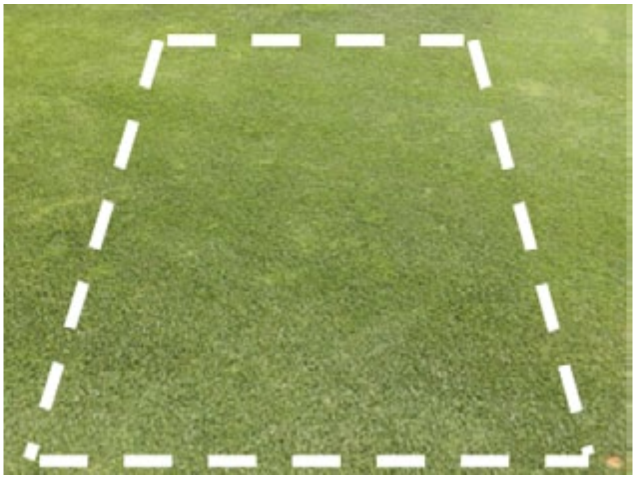
Results

The growing season of 2013 could be considered normal by many standards. A relatively wet spring was followed by a fairly dry summer and fall with moderate temperatures throughout. The total number of season-long applications required following the 400 GDD model was seven, while four applications were required when following the 800 GDD model. In warmer years, the frequency of applications would increase when using these models.

Primo treatments at 24fl.oz per acre on 400 growing degree days provided the most inconsistencies in turfgrass quality, chlorophyll index (color), and clipping biomass throughout the growing season. Generally, Primo treated plots had the lowest turfgrass quality in the spring and early summer, followed by the highest turfgrass quality in the late summer and fall. Chlorophyll index ratings closely matched the responses in turfgrass quality and the same trends were observed (Figure 1). Clipping biomass correlated closely to turfgrass quality and color, with approximately 75% yield reduction in the spring and 30% yield increase in the fall. A possible explanation for these results could be that this area was not treated with Primo previously and the 24fl.oz. per acre rate was excessive for the initial applications. The increased biomass in the late summer can be attributed to a reallocation of carbohydrates from shoot growth to tiller growth, causing an overall yield increase as compared to the untreated control. Trimmit applications provided little increase in turfgrass quality or color in the spring and summer as compared to the untreated control.

In the fall, all Trimmit treated plots received greater turfgrass quality and color ratings than the control; this could be attributed to lower shoot growth rates and higher densities (Images 1 and 2).

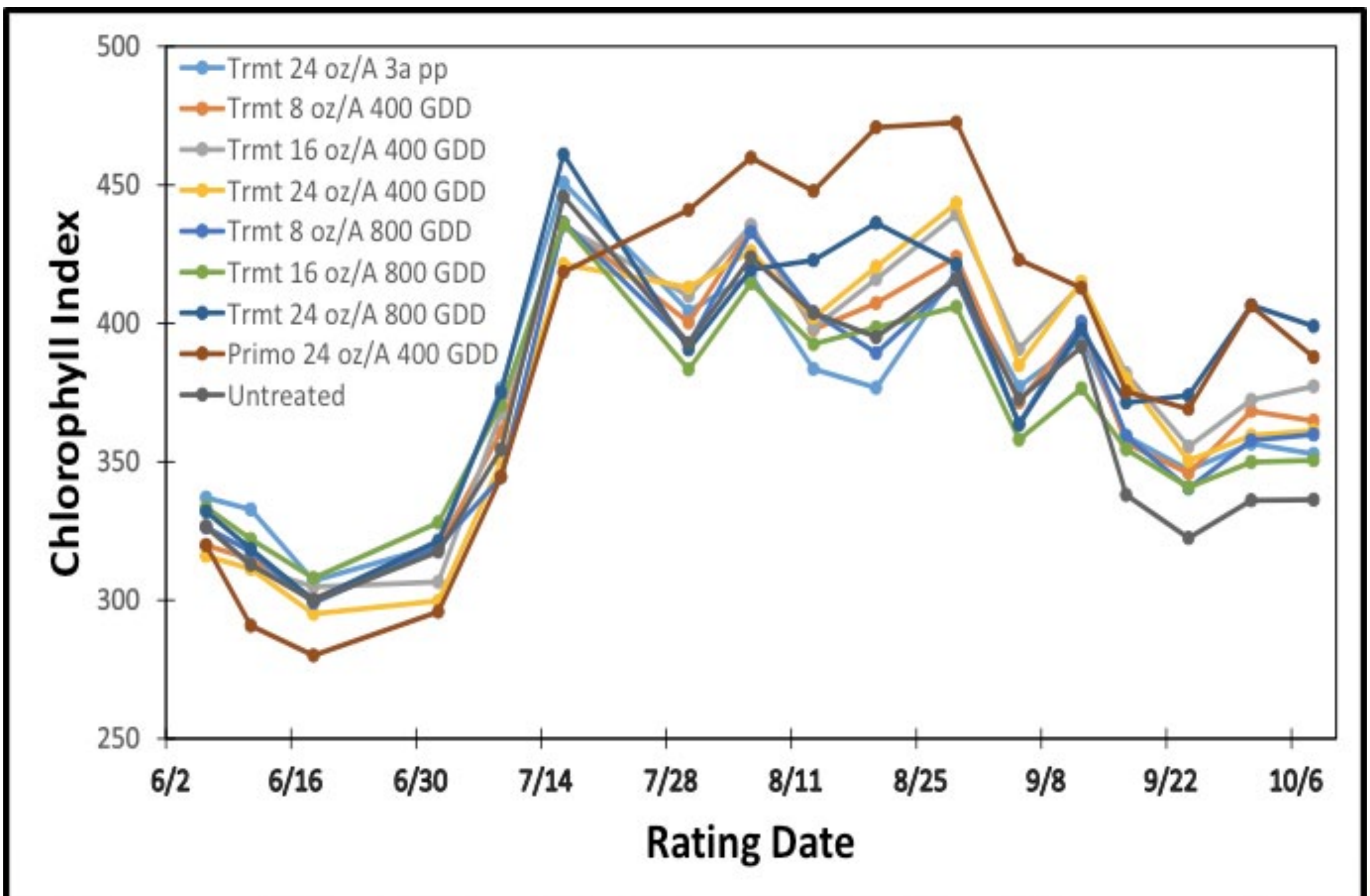




Above: On left an untreated control plot image taken on September 17th, 2013. On the right Trimmit application of 16 fl. oz/acre applied at 800 GDD. This picture was taken on September 17th also.

Trimmit treatments suppressed biomass production to a greater extent in the spring and summer than in the fall, which is similar to what was witnessed with Primo and the same explanation would be valid. The most consistent and desirable suppression from Trimmit was achieved by applications of 8 and 16fl.oz. acre^{-1} at 400 GDD (approximately 20% and 35% growth reduction, respectively) or 16 and 24fl.oz acre^{-1} at 800 GDD (approximately 30% growth reduction).

Figure 1. Chlorophyll index ratings across 9 different treatments throughout the 2013 growing season from a Spectrum CM1000 chlorophyll meter. This meter estimates chlorophyll content by comparing reflection of 700nm and 840nm light and uses a scale of 0 to 999 (0= no chlorophyll, 999= highest chlorophyll). This measurement is a non-subjective estimate of canopy greenness. Trmt = Trimmit



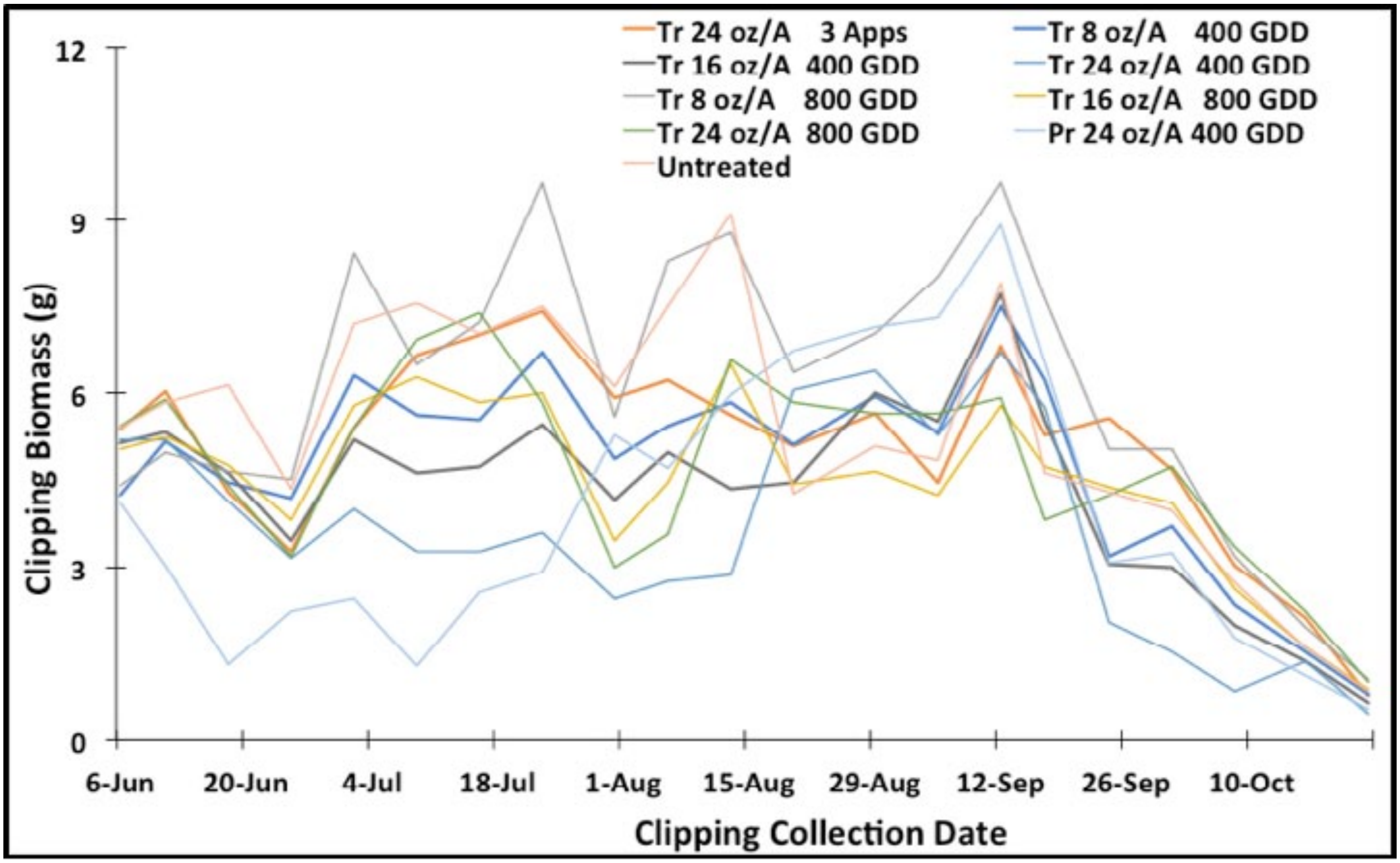


Figure 2. Clipping biomass results from weekly collections throughout the growing season. The most desirable treatments are represented by consistent biomass production, whereas drops and peaks would be considered undesirable. Tr = Trimmit, Pr = Primo

Phototoxicity occurred on several rating dates in June and July as a result of Primo applications, and therefore we recommend starting with rates initially below 20fl.oz per acre. Additionally, minor phototoxicity occurred in July from 16 and 24fl.oz per acre applications of Trimmit applied at 400 GDD, so consider lower rates during this period because higher temperatures will cause growing degree days to accumulate quickly, resulting in more frequent applications during this time.

Discussion

The use of PGRs in a fairway program is easily justified due to the benefits in mowing reduction, improved turfgrass quality and health, more consistent playability, and possible annual bluegrass reduction. We did not see a reduction of annual bluegrass in a Kentucky bluegrass fairway with any PGR treatments, however, and this can be attributed to a similar metabolism of TE and PAC by both species. Creeping bentgrass metabolizes PAC at a more rapid rate than annual bluegrass, which is the main reason that PAC works to reduce annual bluegrass in creeping bentgrass turf.

Both PGRs evaluated in this study improved turfgrass quality and color over the untreated control at some point throughout the growing season. The high rate of both Primo and Trimmit (24fl.oz per acre) applied at 400 GDD produced an undesirable reduction in quality and growth in the spring and early summer, however, these were some of the best treatments in the fall and late-fall. These inconsistent responses throughout the growing season make the frequent high rate applications difficult to recommend. When designing a plant growth regulator program for any turfgrass surface, superintendents should consider the goals of the program and plan applications to meet these goals. If reduced mowing is the main goal and some discoloration is acceptable, frequent high rate programs will provide the maximum level of suppression. If the desire is to balance consistent, moderate suppression with high quality, than application rates and frequencies should reflect this. In this study, high season-long quality and consistent suppression (20-30%) of Kentucky bluegrass was achieved with Trimmit at rates of 8 to 16fl.oz per acre applied every 400 GDD, or 16 to 24fl.oz per acre applied every 800 GDD. We are currently evaluating growing-degree-day programs for both paclobutrazol and flurprimidol on creeping bentgrass fairways in a cooperative project with the University of Illinois. We expect these results to be available in the near future.

Acknowledgements

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References

Branham, Bruce and Beasley, Jeffrey. 2007. PGRs: Metabolism and plant responses: Understanding how PGRs work can help superintendents use these products to benefit the turf and the golf course. Golf Course Management. July. 75(7): 95-99.

Kreuser, Bill and Soldat, Doug. 2012. Precise PGR applications on greens: To suppress turfgrass yield throughout the season, use growing degree days to schedule Primo Maxx applications. Golf Course Management. August. 80(8):80-82, 84, 86, 88.

Soldat, Doug. 2011. Minimizing annual bluegrass encroachment with Trimmit: A growing degree day approach. The Grass Roots. January/February. 40(1): 8-9.

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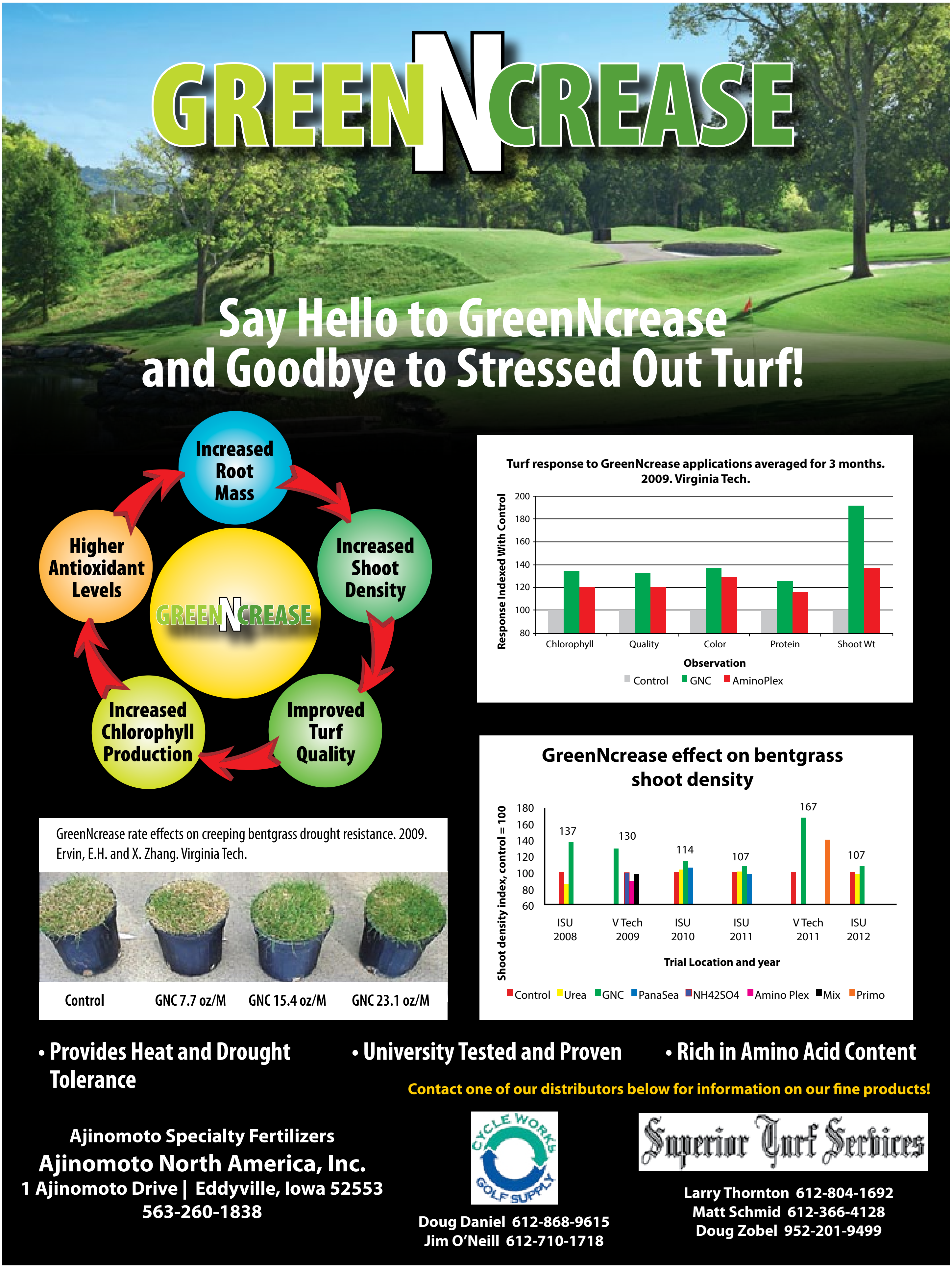
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120
100
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Quality
Color
Protein
Shoot Wt
Observation
Control
GNC
AminoPlex
GreenNcrease effect on bentgrass shoot density
Shoot density index, control = 100
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160
140
120
100
80
60
137
130
114
107
167
107
ISU 2008
V Tech 2009
ISU 2010
ISU 2011
V Tech 2011
ISU 2012
Trial Location and year
Control
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GreenNcrease rate effects on creeping bentgrass drought resistance. 2009. Ervin, E.H. and X. Zhang. Virginia Tech.
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