# How Growth Regulators Change Putting Green Nitrogen Requirements

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Application of nitrogen (N) is a cornerstone of successful and sustainable putting green management. It is well known that an adequate amount N fertility sustains turfgrass color, stand density, and allows for recovery from stress and wear. However, determination of the amount of N to apply is not a simple task. Dr. Carrow et al. (2001) has outlined many of the factors that need to be considered to estimate how much N fertilizer should to be applied during a growing season (i.e. weather conditions, site conditions, level of play/wear, soil N mineralization, etc.). Many of these factors are difficult, if not impossible, to predict. Therefore, historical experience is commonly used to both estimate and schedule N applications during a growing season.

The reason we apply N is to replace N that has been made unavailable to the turfgrass plants. Nitrogen is made unavailable by losses of N from the soil (removing clippings, leaching, denitrification, and volatilization) and N immobilization by soil microbes. Nitrogen immobilization is often overlooked by turfgrass professionals. It's easy to think that every bit of N applied as fertilizer is available to the turfgrass plant when we take care to minimize leaching and other losses (except removing clippings). However, a majority of applied N fertilizer is quickly tied by soil microbes up (immobilized and unavailable to plants). This pool can eventually be mineralized (made plant available) later in the growing season or during future growing seasons. Unfortunately scientist have not yet determined a method to estimate how much N is immobilized within a particular soil or when and how much N will mineralize into plant available forms.

Direct N loss for the system is much more intuitive. Processes such as N leaching, denitrification, and ammonia volatilization are pathways of N lose that are very difficult to estimate and measure, but are normally minimized by routine management practices such as spoon feeding and not applying before large rain events. Nitrogen loss during mowing and clipping removal is the largest, and most consistent pathway of N loss. Removal of clippings during mowing doubles the N fertility requirements of Kentucky bluegrass lawns (Heckman et al., 2000; Kopp and Guillard, 2002). Because of this, most university recommendations state N fertilization should roughly match N removal during mowing. If you've been a regular *The Grass Roots* reader or have attended UW Turfgrass Field Day over the past five years you're probably heard about our GDD system to schedule Primo Maxx applications (trinexapac-ethyl, Syngenta Co.). We found that Primo Maxx can suppress putting green clipping yield for the entire growing season when it was applied every 200 growing degree days (base zero degrees Celsius; for more information reference the Sept/Oct 2009 issue of *The Grass Roots*). In order to complete this research we had to collect clipping yield every other day during the entire growing season. Out of curiosity, we decided to calculate how much N was removed during mowing be multiplying the total dry clipping mass by the average clipping tissue N content. To our satisfaction we found that our fertilizer rate roughly equaled N removal during mowing on plots not treated with Primo Maxx. However, plots treated with Primo Maxx every 200 GDD or less had significantly less N removal per week with enhanced turfgrass quality than the control. This led the question, "How do PGRs reduce putting green N requirement?" To answer this question we designed a three year study to better understand how growth regulators affect putting green N fertility requirements.



**Experimental Design**

This design of the study was simple. The study was conducted on a two year old 'Memorial' creeping bentgrass golf putting green, mowed six days a week at 0.125 inches and irrigated daily to 80% of potential evapotranspiration. There were a total of six treatments replicated four times for a total of 24 plots. The treatments included three N fertilizer rates of 0.1, 0.2, 0.4 lbs N/M applied every two weeks from urea with or without Primo Maxx. For ease of discussion the 0.1, 0.2, and 0.4 lb rates will be referred to as the half, standard, and double N rates, respectively. Both the urea fertilizer and Primo Maxx was applied with a CO2 powered backpack sprayer equipped with TeeJet AI 11004 nozzles and calibrated to deliver 2 gal/M. Approximately 0.2 in of irrigation was applied to the surface immediately following urea application to reduce potential volatilization. In 2008 Primo Maxx was applied every 3 weeks at 0.125 oz/M. This was amended in 2009 and '10 to 0.25 oz/M every 200 GDD.

Turfgrass visual quality, color index (measured with a Spectrum CM1000), and clipping yield were measured prior to fertilizer application every two weeks. Turfgrass quality was rated on a 1 to 9 scale where one represents completely dead, six represents minimally acceptable, and nine represents perfect putting green turfgrass visual quality. The Spectrum CM1000 measures the reflectance of light off the turfgrass leaves to estimate the chlorophyll content and subsequent green color of the leaves on a scale of 0 to 999 (larger numbers represent a higher green color). Clipping yield was measured by mowing one eight foot pass down the middle of each plot with a Toro 1000 walking greensmower. Clippings were then dried, clean of sand debris, weighed. Clippings from one sampling date per month were analyzed for tissue N content. Nitrogen removal during mowing was calculated by multiplying clipping mass by N content. All data was analyzed with JMP statistical software using repeated measures analysis and Fisher's LSD for mean separation. The results were summarized below.

**Results**

Putting green clipping yield responded linearly to N rate during all three years. We found that doubling N application rate increased clipping yield by approximately 25%, which is similar to other research (Schlossberg and Schmidt, 2007). This is significant because doubling N fertility rate did not double clipping yield which is a concern of many golf course superintendents.

In 2008, Primo Maxx was applied every three weeks. This re-application interval did not suppress clipping yield for the entire season. The application schedule needed to be changed in 2009 and 2010 to assess how consistent yield suppression affects N requirements. Application of Primo Maxx every 200 GDD statistically suppressed clippings on 17 of the 19 rating days in '09 and '10. This application regime resulted in an average yield suppression of 20% (a value similar to our other putting green studies with Primo Maxx). Although less suppression than stated on the label, application of Primo Maxx still reduced clipping yield by a similar level as reducing N rate by 50%, a substantial decrease.

As you'd expect, an increase in N fertilizer rate led to more N in the leaf tissue. Additionally, tissue N contents were highest during mid-summer when creeping bentgrass is vigorously growing in Wisconsin. Primo Maxx did not affect the level of N in the leaf tissue regardless of how often it was applied in any year. Nitrogen removal during mowing is calculated by multiplying dry clipping yield mass by the amount of N in the dry clippings. Since Primo Maxx reduced clipping yield by 20% yet did not affect the amount of N in the tissue, Primo Maxx also reduced N removal by 20%. This means that plant growth regulators, such as Primo Maxx, increase retention of N in the turfgrass ecosystem but only when they are applied with a GDD system to prevent the growth surge or rebound phase.

Turfgrass color index and visual quality rating increased with N rate, again as you'd expect. Turfgrass visual quality ratings were not different on the first rating date of 2008, values around 6.5. However, the three N treatments slowly diverged over the course of three growing season (Fig. 1). Primo Maxx did not change turfgrass quality rating in 2008 because it was re-applied too infrequently. But in 2009 and 2010, Primo Maxx enhanced turfgrass visual quality compared to the non-treated control because it was applied every 200 GDD. This was especially true in 2010 when Primo Maxx enhanced visual quality on seven of the nine rating dates. Increased color likely improved because Primo alters plant physiology (i.e. increased cell density, tillering, etc.) but likely also increased because more N was retained in the soil (less clipping removal).

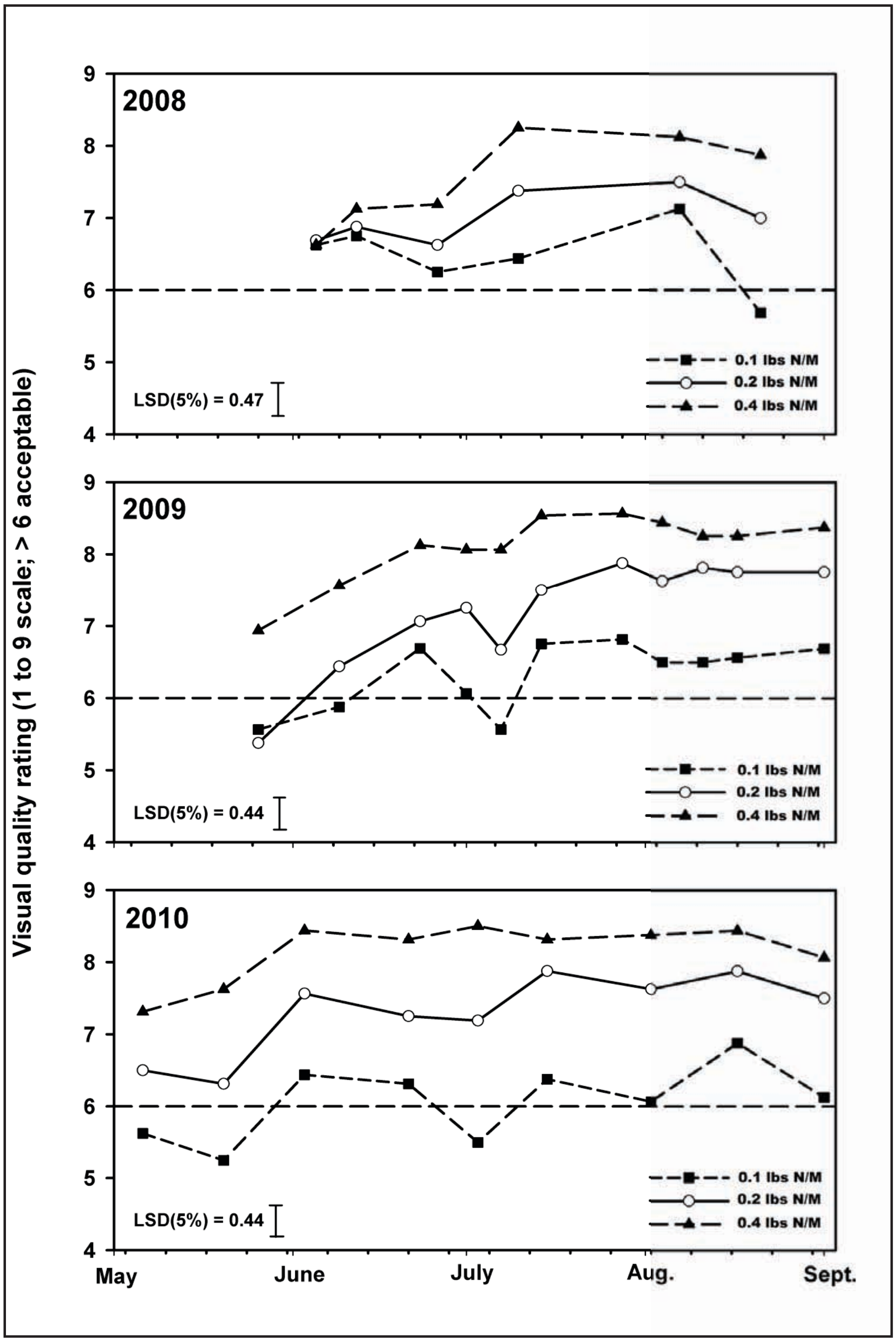


**Figure 1. Visual turfgrass quality rating as affected by nitrogen application rate. Turfgrass visual quality rating was the same initially and then diverged over the course of three years. Doubling N rate typically increased quality by one unit. Nitrogen was re-applied every two weeks. Visual quality was rated on a one to nine scale where one represents completely dead, six minimally acceptable, and nine perfect putting green quality. The dashed line indicates the minimally acceptable threshold.**

**The Role of the Soil N Pool**

Remember that a majority of the applied fertilizer N is immobilized by the soil and the majority of the N in the plant comes from the soil N mineralization. When N fertilizer rate exceeds removal then N either accumulates in the soil or is lost (usually via leaching or denitrification). When removal during mowing exceeds N fertilization there soil N supply slowly declines. This process can take many years to occur and can be seen in Figure 2. Notice how turfgrass quality rating and color decreased from 2009 to 2010 for the half rate treatment. The opposite happened for the double N rate treatment. Turfgrass quality and color of the standard N rate was statistically unchanged from 2009 to 2010. Again, all treatments had the same color and visual quality rating at the beginning of the study. Also, the addition of Primo Maxx further helped to sustain color and visual quality when averaged across all the N treatments.

To verify our hypothesis we calculated a simple N budget (N fertilizer application subtracted from N removal during mowing). Negative values indicate a soil N deficit and positive values indicate a soil N surplus. The values were then plotted with N rate on the x-axis (Fig. 3B), and the point on the where the line crosses from the negative to the positive represents the break-even point (the ideal N fertilization rate). Clearly the half N rate treatment (0.1 lb N/M) led to a soil deficit and the double N rate a soil N surplus. The standard rate was the treatment closest to the break-even point of 0.15 lbs N/M every week. Addition of Primo Maxx shifted the break-even point left to 0.1 lbs N/M. This analysis shows why visual quality and color diverged during this study.

The take home message is that changes in your N fertilization program may not be obvious for many years. For example, if next year we reduced the double N rate treatment to the same rate as the half N rate treatment, the turfgrass visual quality and color would not drastically change because soil N can make up the difference for several years.

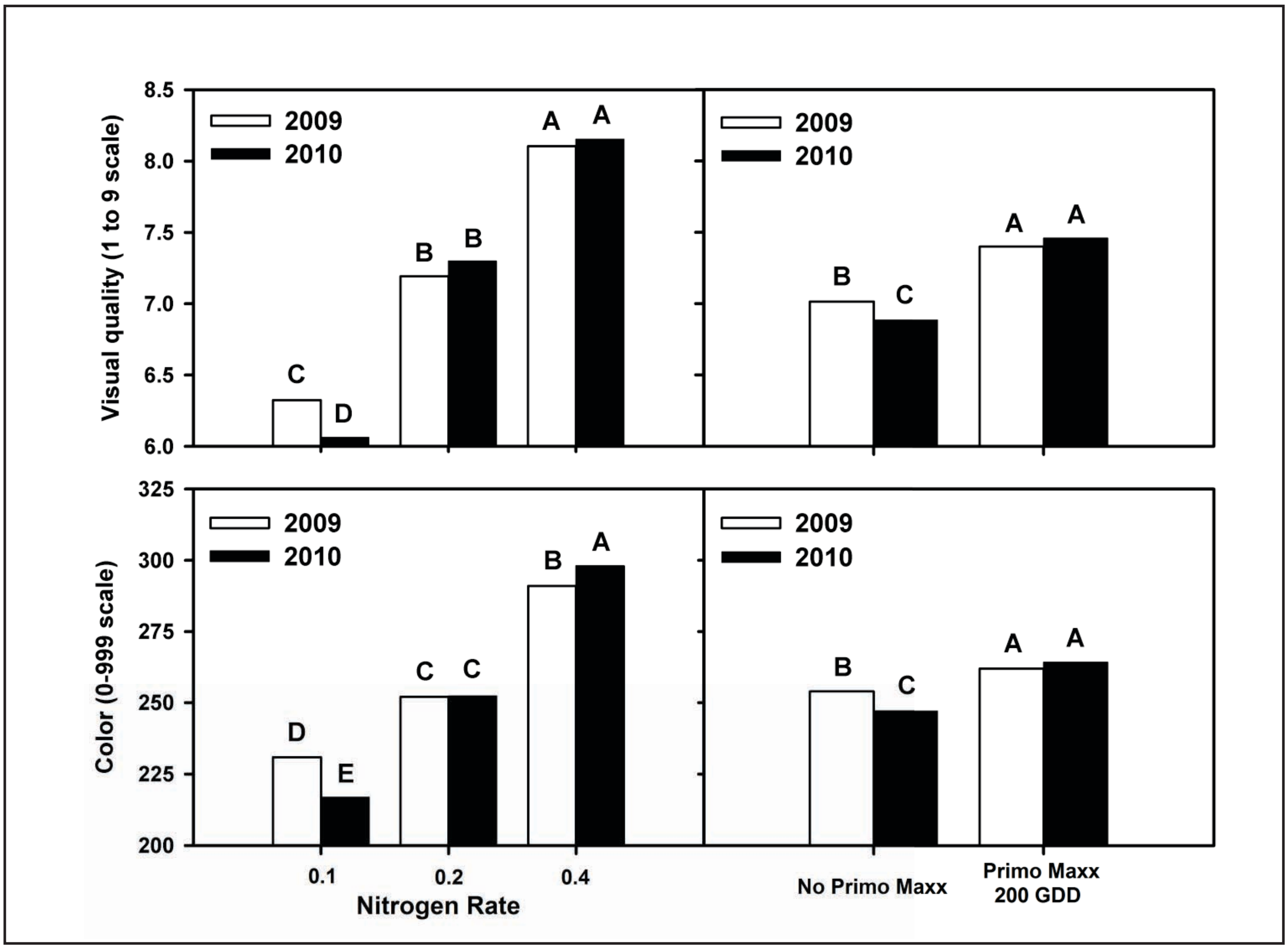


**Figure 2. Yearly average color index and turfgrass visual quality rating at different N rates and Primo Maxx treatments. Application of 0.2 lbs N/M every two weeks sustained turfgrass color and quality. Fertilizer less than that point led to decline in color and quality from 2009 to '10. The opposite occurred for treatments receiving more than 0.2 lbs N/M. Primo Maxx increased both turfgrass color and quality. It also prevented quality and color decline from 2009 to '10. Color index was measured with a Spectrum CM1000 reflectometer.**

Eventually the soil N bank will go broke and the green will struggle to recover from stress and wear. When the problem finally is noticed several years later, it wouldn't be obvious that low N fertilization caused the green to decline because the fertility had been the same (low) for many years while the green performed well.

**How Do PGRs Change Putting Green Fertility Requirements**

To visualize how Primo changed putting green N requirements, average clipping yield, color index, N removal, and N budget were plotted with and without Primo and N application rate on the x-axis (Fig 3). Notice that Primo Maxx shifted the regression line for dry clipping yield and N removal to the right (Fig 3A&C). This means that the double N rate with Primo had the same clipping yield and N removal as standard treatment without Primo. Similarly, the standard N rate with Primo Maxx has similar yield N removal as the half rate without Primo Maxx. There was some variability in this trend but on 33 of the 38 possible occasions, Primo Maxx reduced clipping yield by the same amount as a 50% reduction in N rate.

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Alternatively, Primo Maxx shifted the regression line for turfgrass color and N budget break-even point to the left (Fig. 3B&D). This means that N fertilization rate would need to be increased by 50% to obtain similar turfgrass color and break-even point as a plot treated with Primo Maxx every 200 GDD. Simply put, the addition of Primo Maxx increased color by the same amount as increasing monthly N fertilization by 0.1 lb N/M.

There were also many days where Primo Maxx increased color similarly to a 100% increase in N rate, particularly during late summer and early fall. Figure 4 shows a picture of the double N rate treatment without Primo and the standard N rate treatment with Primo applied every 200 GDD. Note how much these two plots look alike.

**How Have PGRs Changed the N Requirements of YOUR Putting Greens?**

The answer of this question first depends on how often you applying your favorite growth regulator. If it is approximately 200 GDD for trinexapac-ethyl (Primo Maxx) or 300 GDD for paclobutrazol, then your N fertility requirements have already changed. However, if your PGRs are being applied too infrequently or never applied, expect to see a change once PGRs are applied on a more regular basis. For example, the treatment receiving 0.2 lbs. N/M every two weeks with Primo would have a similar clipping yield as a plot fertilized with 0.1 lb. N/M without Primo. Additionally, the turfgrass color and quality would be similar to a plot receiving 0.15 lbs. N/M every two weeks without Primo. In this case it may be possible to reduce N fertilization rate slightly with no loss of turfgrass color and visual yet clipping yield would be substantially less from reduced N fertilization rate and yield inhibition from the PGRs.

**Conclusions**

Use of PGRs to suppress clipping yield during an entire growing season significantly reduces turfgrass fertility requirements. We found that Primo Maxx applied every 200 GDD can reduce fertility requirements by conservatively 25%. This occurs because Primo reduces N removal during mowing (a major source of N loss) and Primo Maxx increases turfgrass color and tiller density by manipulating plant hormone levels. Turfgrass color and visual quality were sustained from year to year when N fertilization roughly matched N removal from mowing, supporting many university recommendation. Since Primo reduced N removal it therefore reduced N requirements. This study is currently being published in much more detail in Crop Science if you'd like more information. As always, if you have questions feel free to contact me at wck38@cornell.edu or Dr. Soldat at djsoldat@wisc.edu.

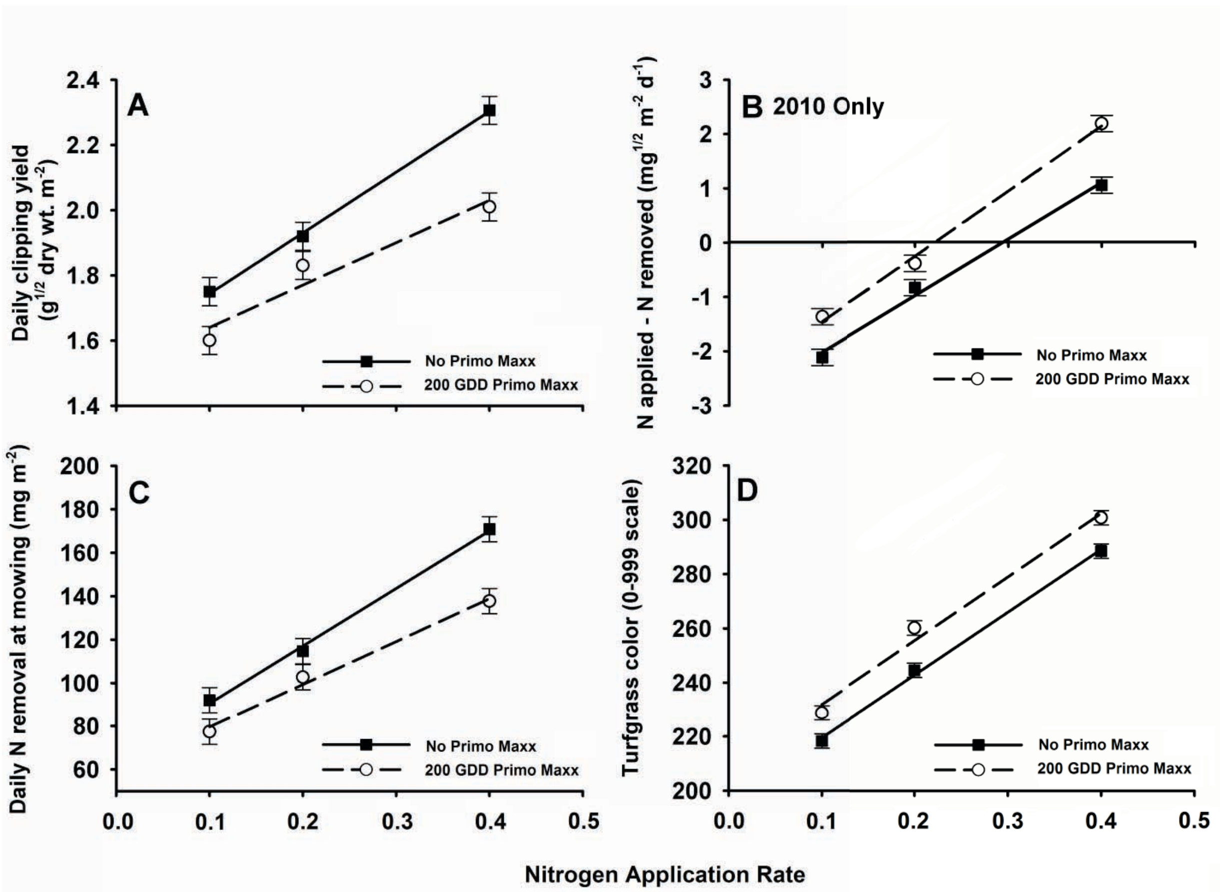


**Figure 3. Nitrogen rate response curves. A: Primo reduced clipping yield similarly to cutting the N rate in half. B: Primo reduced the optimum fertilization level from 0.3 to 0.2 lb N/M every two weeks (the break-even point where fertilization rate matched N removal during mowing). C: Primo reduced N removal similarly to cutting the N rate in half. D: Primo increase color similarily to increasing N rate by 50%/**


**Figure 4. Photograph showing how repeat Primo Maxx applications can reduce putting green nitrogen requirements. The plot on the right with Primo has similar turfgrass quality as the plot on the left without Primo despite the difference in N application rate.**

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