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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).


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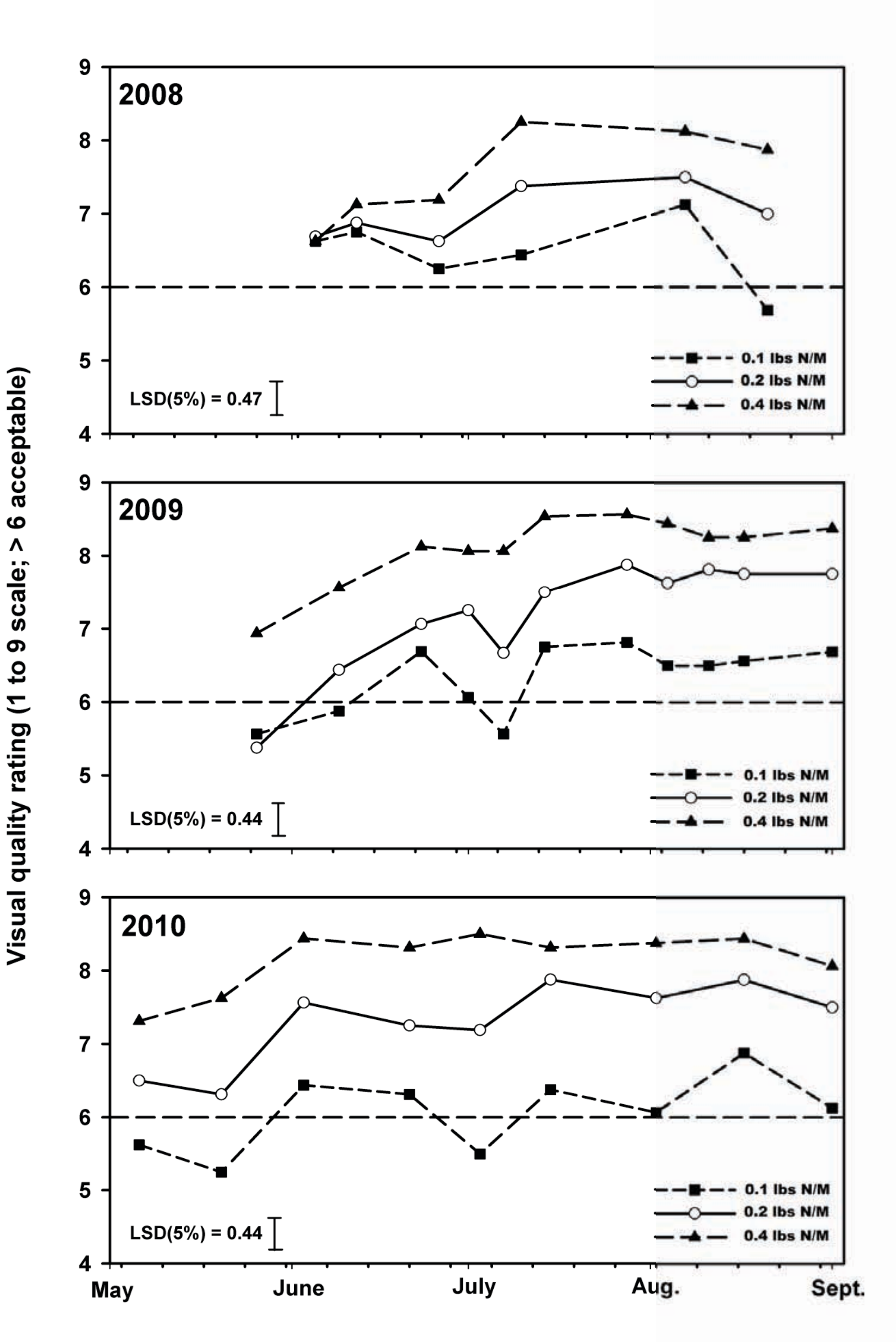

Figure 1. Visual turfgrass quality rating as affected by nitrogen application rate. Turfgrass visual quality rating was the same initially and then diverged over the course of three years. Doubling N rate typically increased quality by one unit. Nitrogen was re-applied every two weeks. Visual quality 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.

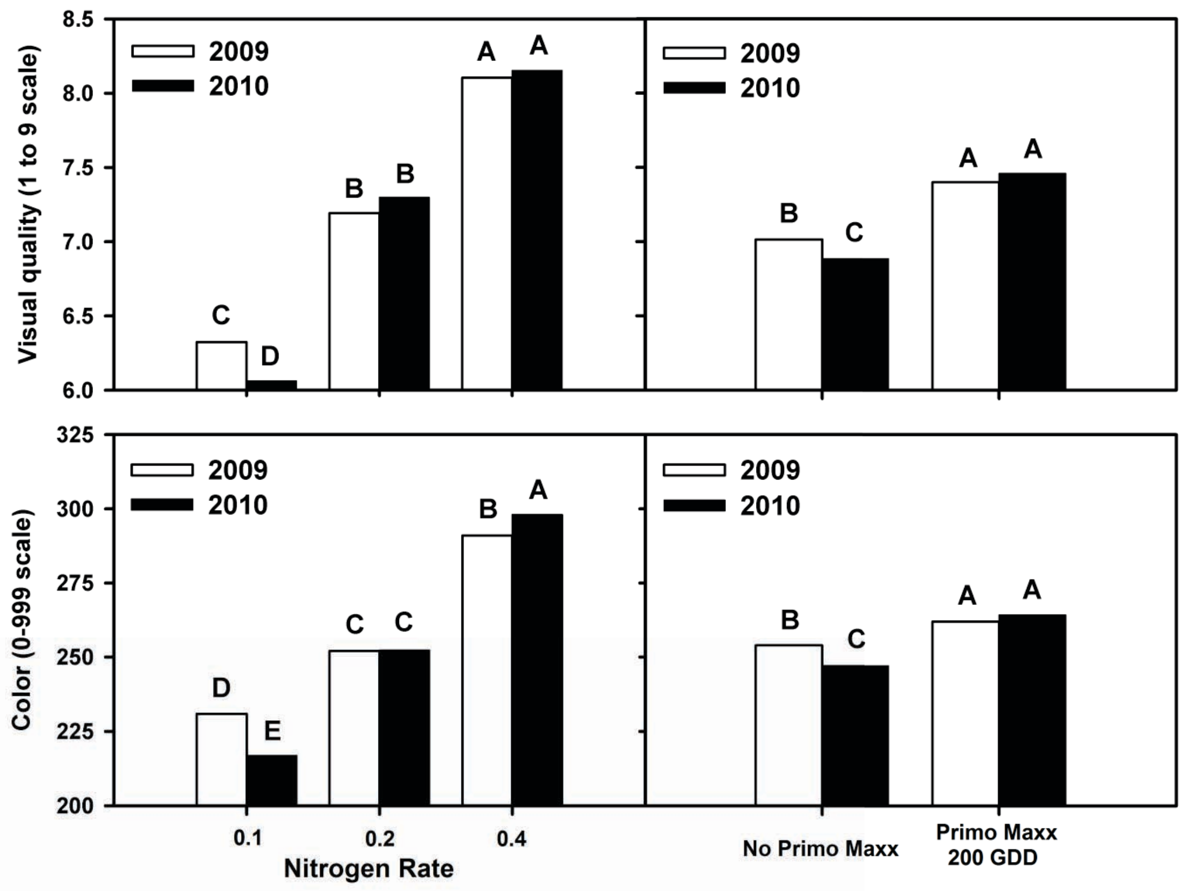

Figure 2. Yearly average color index and turfgrass visual quality rating at different N rates and Primo Maxx treatments. Application of 0.2 lbs N/M every two weeks sustained turfgrass color and quality. Fertilizer less than that point led to decline in color and quality from 2009 to '10. The opposite 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.

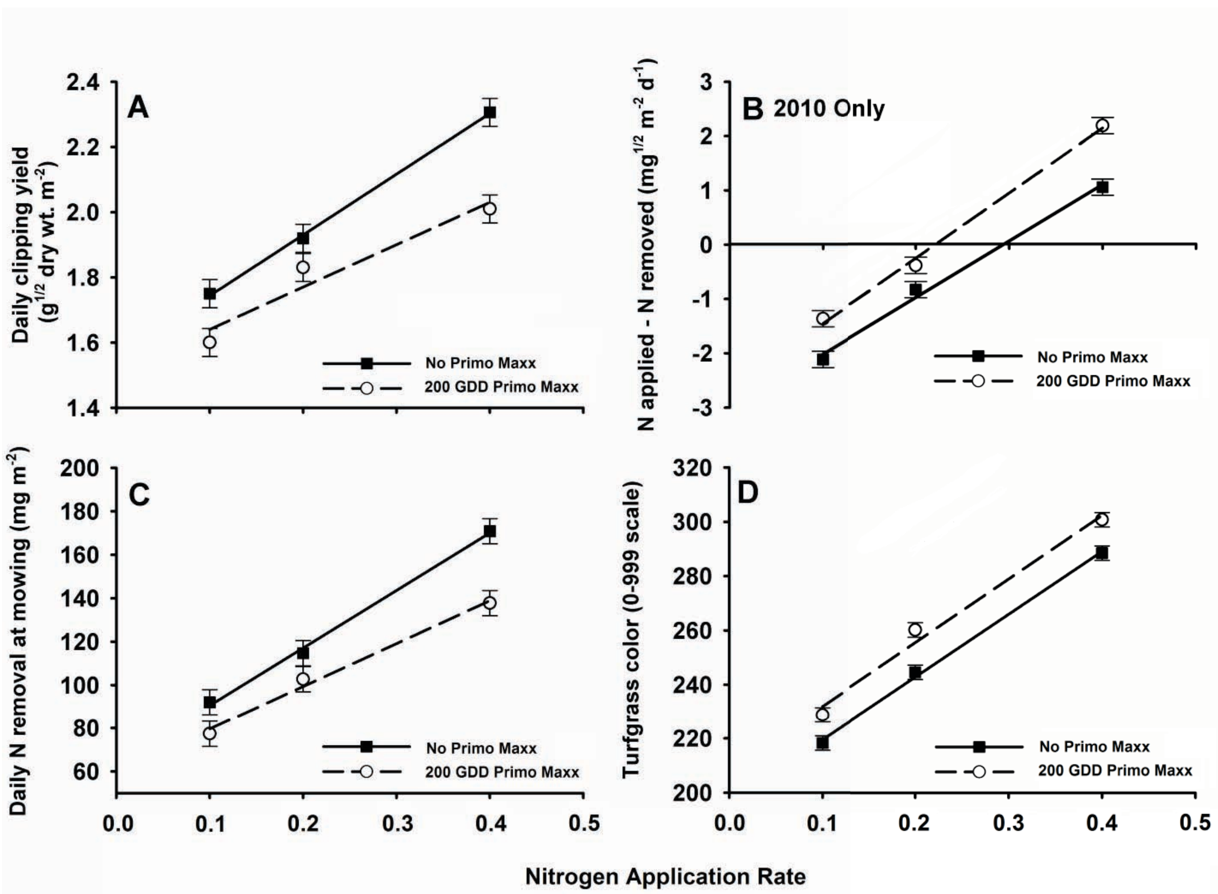

Figure 3. Nitrogen rate response curves. A: Primo reduced clipping yield similarly to cutting the N rate in half. B: Primo reduced the optimum fertilization level from 0.3 to 0.2 lb N/M every two weeks (the break-even point where fertilization rate matched N removal during mowing). C: Primo reduced N removal similarily 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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A Review of Phosphite Products and Their Efficacy

By Dr. Jim Kerns, Department of Pathology, University of Wisconsin - Madison

Phosphite products have undoubtedly become extremely popular with golf course superintendents. It seems like every superintendent is applying a phosphite product of some kind or another. While phosphites do have their place and are effective, it is important to understand these products and their limitations. These products are composed of esters or salts of phosphorus acid and many have fosetyl-Al or potassium phosphite as active ingredients. Phosphite products are thought to have a dual mode of action that involves direct effects on the pathogen and indirect effects by stimulating plant defense responses (4). For an excellent review of phosphite products, I suggest reading 'Landscoot and Cook 2005. Sorting out the phosphonate products' published in Golf Course Management 73 (11), pgs 73-77 (3). Many studies have demonstrated the effectiveness of phosphite products, but few have conducted the experiments in a way to compare apples to apples. This article will review two studies that equally compared phosphite products in lab and field experiments.

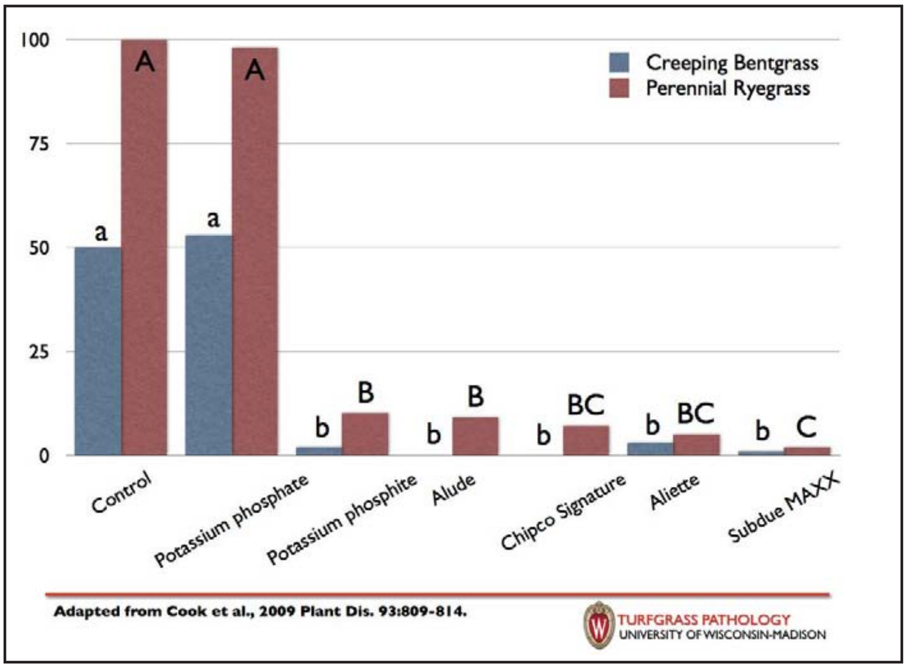

Figure 1. Suppression of Pythium blight on creeping bentgrass and perennial ryegrass in Pennsylvania. All treatments except for Subdue MAXX (applied at 1 fl oz/M) were applied at rates that supplied 8.56 lbs. of phosphoric acid/acre. This was based on the intermediate rate for Alude 7.4 fl oz/M. Bars with the same lower case letter (creeping bentgrass treatments only) are not significantly different. Bars with the same upper case letter (perennial ryegrass treatments only) are not significantly different. Data adapted from Cook et al., 2009. Plant Dis. 93:809-814.

A relatively recent paper published in Plant Disease by Cook et al., (2009) examined the efficacy of phosphonate fungicides (Alude, Chipco Signature, Aliette, and a two reagent grade solutions designed to yield potassium phosphite and potassium phosphate) on Pythium blight of perennial ryegrass and creeping bentgrass. The field experiments were conducted in a 'mist chamber' constructed over field plots. In conjunction with this study, the authors investigated the in vitro (in cultures) sensitivity of Pythium aphanidermatum (one of common the causal agents of Pythium blight in turf) to various concentrations of phosphorous acid and phosphoric acid. The sensitivity of the Pythium aphanidermatum isolates used in their field study ranged from 94.6 to 134.3 ppm, which seems quite high (1). Yet when the phosphonate fungicides were applied at 8.56 lbs of phosphoric acid per acre (this equates to an intermediate rate of 7.4 fl oz/M), Pythium blight suppression was observed with each treatment. Suppression was equal to that observed with applications of Subdue MAXX applied a 1 fl oz/M (Figure 1) (1). The authors demonstrated that phosphoric acid does inhibit mycelial growth of various Pythium species including Pythium aphanidermatum, but more importantly that when applied at an intermediate rate can suppress Pythium blight development.

Another experiment conducted by Ervin et al. (2) followed up on the work conducted in Cook et al. (1), except without the use of a mist chamber and inoculation. In their study, field plots were established on a perennial ryegrass fairway in Virginia and they did not inoculate the experimental area. However, Ervin et al. (2) also reported excellent suppression of Pythium blight with many phosphite products. In some cases the suppression was as good or better than a 1 fl oz rate of Subdue MAXX (Figure 2). However the authors observed considerable differences in efficacy across years (Figure 2). In their study, Signature performed the best in both years. In 2006, the other treatments did not perform as well, but still suppressed disease when compared to the non-treated control (2).


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What does this all mean for the practitioner? First, phophite products are effective and can be a nice part of a disease management program. The problem is deciding a rate to apply them. It seems like the rate of 8.5 lbs of phosphoric acid per acre worked exceptionally well in the Cook et al. (1) experiment and would be the rate to consider if you are considering phophite products for the first time or are looking to adjust your current program.

This is problematic because many of the products registered as fungicides have already determined rates that are effective. If you are using products that are not registered as fungicides through EPA, then you will have to calculate rates that provide the appropriate amount of phosphoric acid. In any case, the important number to know is how much phosphoric acid these products contain. Furthermore, the results from the Ervin et al. (2) demonstrate that results with any product, vary from year to year and one should not expect excellent results each year. In summary, the use of a phosphite product alone in some years may not be enough to prevent Pythium blight. These products are only effective if they are applied prior to disease development and are best used as part of a program. Applications of phosphites once Pythium blight develops typically does not help, once the disease has developed then the use of Subdue MAXX, Banol, Stellar, and Segway could be your best options.

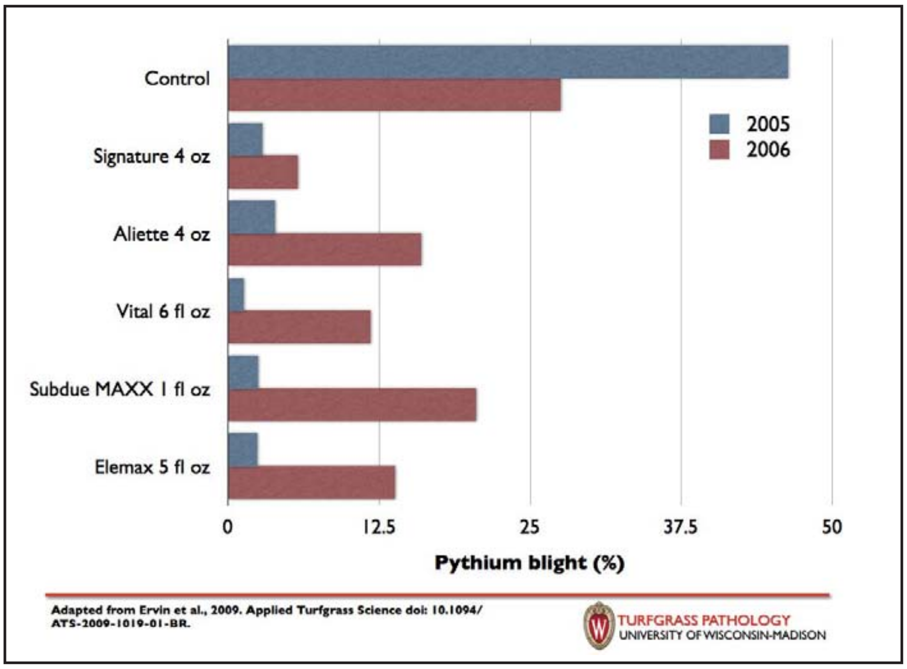

Figure 2. Pythium blight suppression using various phosphite products on a perennial ryegrass fairway in Virginia. Rates were applied for 1000 ft2 and were applied 4 times every 14 days June through early August. Data shown is from the August 12 rating date for both 2005 and 2006. The experimental area was not inoculated. Data was adapted from Ervin et al., 2009. Applied Turfgrass Science doi: 10.1094/ATS-2009-1019-01-BR.

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