



Potassium Phosphite Comparison

EPA Labeled Fungicides				Phosphite Fertilizer Labels**							
Product	Kphite 7LP	Reliant Systemic Fungicide	ALUDE	Green Flo Phyte	Nutri-Grow Magnum	Phyto Fos™ K	Phyte-Off™	P-K Plus	Phosphite 30	Phosphite 40	Stress Phiter
Manufacturer Analysis	Plant Food Systems Fungicide	Agrisel USA Fungicide	Cleary Chemical Corporation Fungicide	LESCO 0-0-18	Cleary Chemical Corporation 2-40-16	ADVAN LLC 0-0-18	ADVAN LLC 0-0-26	Griggs Brothers PK Plus 3-21-18	Plant Food Company 0-30-27	Plant Food Company 2-40-16	AGRICHEM Private label 0-0-30
% Mono-and di-potassium salts of Phosphorous Acid	56.00%	45.80%	45.80%						56.00%		Not Expressed on Label. Calculated the same as Reliant Fungicide:
lbs/gal of Mono and di-potassium salts of Phosphorous Acid. Also known as "Potassium Phosphite"	New for 2008. Higher active than Kphite 7.03	5.17	5.17	2.44	Not Expressed on Label. Calculated as: 7.67	2.44	Not Expressed on Label. Calculated as: 6.22	Not Expressed on Label. Calculated as: 4.57	New for 2008. Higher active than Phosphite 29 7.03	Not Expressed on Label. Calculated as: 6.52	5.17
Pounds of Phosphorous Acid/gallon equivalent	4.41	3.35	3.35		5.48	2.44	2.44	2.46	4.41	4.66	3.64
Bulk Density	12.31	11.29	11.29	11.10	13.7	11.1	11.1	11.72	12.31	11.66	12.14
pH	6.9-7.0	5.5 - 6.0	5.5 - 6.0	3.0 - 7.0	6.5	6.0 - 7.0	6.0 - 7.0	6.7	6.9-7.0	6.5	
Salt Index	8.5				65	42	42		8.5	14	55
Cost per Gallon	\$ 62.20	\$ 49.00	\$ 49.00	\$ 20.00	\$ 60.00	\$ 45.00	\$ 45.00	\$ 48.50	\$ 47.10	\$ 51.35	\$ 35.00
Cost per 2x2.5 gal cs	\$ 311.00	\$ 245.00	\$ 245.00	\$ 100.00	\$ 300.00	\$ 225.00	\$ 225.00	\$ 242.50	\$ 235.50	\$ 256.75	\$ 175.00
Cost per lb of Potassium Phosphite	\$ 8.85	\$ 9.48	\$ 9.48	\$ 8.20	\$ 7.82	\$ 18.44	\$ 7.23	\$ 10.61	\$ 6.70	\$ 7.88	\$ 6.77

Cost per lb of Potassium Phosphite is calculated by dividing the cost per gallon by the lbs per gallon of "Potassium Phosphite."

* The terms "mono and di-potassium salts of Phosphorous acid" is the precise name for Potassium Phosphite

Phosphorous Acid must be neutralized with potassium hydroxide in order to stabilize this in the Phosphite state (PQ) This is accomplished with the "P" and the "K" at a 1-1 ratio.

** Phosphite Fertilizers make **NO CLAIMS** regarding control of any diseases. These products are labeled as a nutrient source.

Phosphonate products for disease control and putting green quality

How does potassium phosphite stack up against fosetyl-Al in controlling *Pythium* blight and anthracnose basal rot?

Joshua Cook; Peter Landschoot, Ph.D.; and Max Schlossberg, Ph.D.

EDITOR'S

note:

In their previous article ("Sorting out the phosphonate products," *GCM*, November 2005, pp. 73-77), the authors reviewed phosphonate terminology, how phosphonate compounds control disease, and their role as fertilizers. In this article, they discuss the results of phosphonate fungicide research conducted on *Pythium* blight and anthracnose, as well as putting green quality.



Photos courtesy of P. Landschoot

Figure 1. A *Pythium* chamber (greenhouse frame covered with plastic) was used to produce conditions necessary for *Pythium* blight development (left). An automatic misting system was used to increase humidity levels (right).

Phosphonate products differ in active ingredient, formulation, trade name, label terminology, uses and price. Detailed studies on how these products perform with respect to disease control and improving turf quality should help you make sound choices on the most appropriate product(s) for your specific needs. The objectives of our research were to determine whether products made with potassium phosphite or fosetyl-Al provide similar control of *Pythium* blight and anthracnose basal rot when applied at equivalent rates of phosphorous acid, the active compound for controlling diseases. We also wanted to determine whether product formulation influences disease control. Our second objective was to evaluate the effects of active ingredient and formulation on putting green quality when applied at equivalent rates of phosphorous acid.

Treatments

Phosphonate fungicides are made up of salts or esters of phosphorous acid. Salts of

phosphorous acid are referred to as phosphites, and phosphite products typically contain a mixture of phosphorous acid and potassium hydroxide (KOH). Phosphite fungicides (Alude, Magellan, Vital, Resyst and others) usually list potassium phosphite or mono- and di-potassium salts of phosphorous acid as the active ingredient on the product label. Esters of phosphorous acid are referred to as fosetyl-Al or aluminum tris (O-

ethyl phosphonate), the active ingredient in Aliette and Chipco Signature fungicides.

All phosphonate fungicides, whether phosphites or fosetyl-Al, are broken down into phosphorous acid following plant uptake. Because phosphorous acid is the compound that controls disease, we compared products based on equivalent rates of phosphorous acid. We did this by determining the molecular weight of phosphorous

TREATMENT RATES

Treatment	Rate/1,000 square feet	Rate/hectare
Potassium phosphate	4.0 ounces	12.2 kilograms
Potassium phosphite standard	43.6 fluid ounces	138.8 liters
Alude	7.4 fluid ounces	23.6 liters
Aliette	5.7 fluid ounces	17.4 kilograms
Chipco Signature	5.7 fluid ounces	17.4 kilograms
Subdue Maxx	1.0 fluid ounce	3.2 liters

Table 1. Treatments and rates used in the *Pythium* blight, anthracnose and putting green-quality phosphonate fungicide studies.

RESEARCH

acid in each product and adjusting the product rates accordingly. The rates of all of the phosphonate fungicide treatments fell within

the range given for *Pythium* blight control on the fungicide labels and for anthracnose control on the Chipco Signature label (Table 1).

Treatments

Treatments for *Pythium* blight, anthracnose and turf quality trials included a commercial phosphite product (Alude); two fosetyl-Al products (Aliette WDG and Chipco Signature); a potassium phosphite standard (made by mixing reagent-grade phosphorous acid with water and adjusting the solution to a pH of 6.2 with KOH); and reagent-grade potassium phosphate (made by mixing reagent-grade phosphoric acid with KOH to raise the solution to a pH of 6.2). The potassium phosphite standard was included as a treatment because we knew nothing was added to the mixture that would enhance the efficacy of the phosphite. Thus, we could evaluate the efficacy of the potassium phosphite without interference from formulation effects.

Potassium phosphate (essentially fertilizer phosphorus) was applied at about the same rate of phosphorus as the potassium phosphite treatment. This treatment was added to ensure that disease suppression was not due to a phosphorus nutrition effect.

Subdue Maxx was applied at the label-recommended rate for *Pythium* blight control (1.0 fluid ounce/1,000 square feet or 3.2 liters/hectare) for comparison with phosphonate. This rate of Subdue Maxx has provided excellent control of *Pythium* blight in our *Pythium* chambers during previous studies.

Pythium blight trials

In 2004 and 2005, we conducted field trials to determine whether the active ingredients and formulations of different phosphonate fungicides influence the degree of control of *Pythium* blight on creeping bentgrass (*Agrostis palustris*). We began the trials by seeding Penncross creeping bentgrass within a greenhouse frame one year before treatment application. The turf was mowed three times each week at a height of 1.0 inch (25.4 millimeters), and the area was fertilized and watered to maintain a dense turf. Just before treatment application, the greenhouse frame was covered with clear polyethylene plastic.

This trial was conducted in the plastic-covered greenhouse frame equipped with an automatic misting system (referred to as a *Pythium* chamber) to ensure warm, humid conditions necessary for *Pythium* blight development in central Pennsylvania (Figure 1). Treatments included the phosphonate fungicides and other treatments listed in Table 1.

PYTHIUM VS. FUNGICIDES, 2004

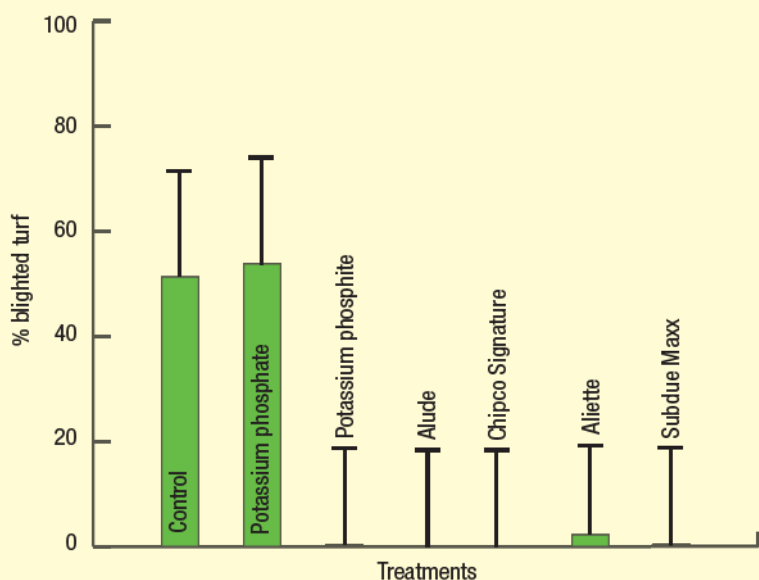


Figure 2. The effect of phosphonate fungicides on *Pythium* blight development of Penncross creeping bentgrass in 2004. Disease is expressed as the percentage of blighted turf. Bars above columns indicate the level of statistical significance.

PYTHIUM VS. FUNGICIDES, 2005

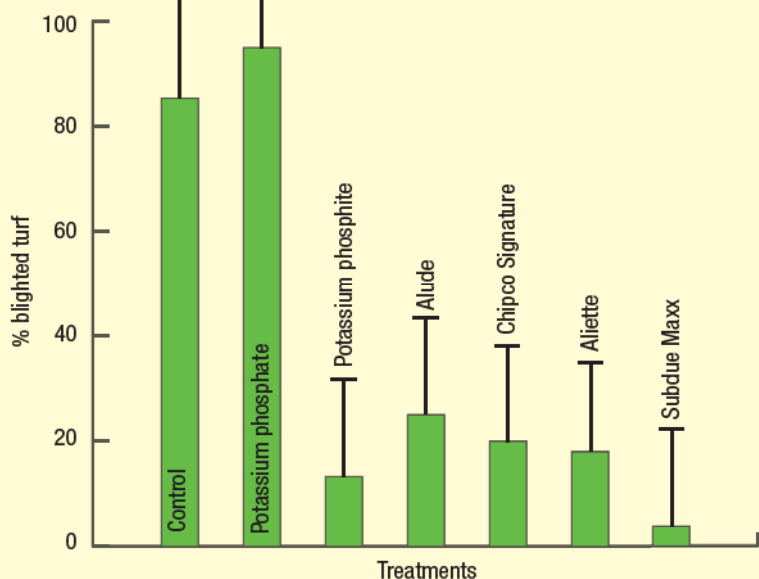


Figure 3. Effect of phosphonate fungicides on *Pythium* blight development of Penncross creeping bentgrass in 2005. Disease is expressed as the percentage of blighted turf. Bars above columns indicate the level of statistical significance.



Figure 4. Plots showing the effects of potassium phosphite standard or H_3PO_3 (left), Chipco Signature (center), and potassium phosphate or H_2PO_4 (right) on symptom development of *Pythium* blight of creeping bentgrass.

Treatments were applied once on Aug. 30, 2004, and again on July 18, 2005. Following treatment application, the open ends of the *Pythium* chamber were closed, and inoculum of *Pythium aphanidermatum* was applied to the test area. Temperature and humidity were controlled with vents that could be opened and closed and an automatic misting system. At the end of each trial, all plots were evaluated for the percentage of area exhibiting blighted turf.

Results

Results showed that *Pythium* blight disease was more severe in 2005 than in 2004, probably as a result of higher chamber temperatures in 2005 (Figures 2, 3). In 2004, phosphonate fungicides (including the potassium phosphite standard) provided good (>95%) control, whereas in 2005, the same treatments showed only 70% to 84% control. Despite seasonal differences in overall *Pythium* blight control, no statistically significant differences occurred among the phosphonate fungicides in either year of the study. This indicates that products with phosphites and fosetyl-Al as active ingredients provide similar *Pythium* blight control (Figure 4). Results also suggest that the formulation of individual products do not appear to have any advantage with respect to *Pythium* blight control.

The potassium phosphate treatment and the untreated control had no effect on disease, indicating that phosphorus nutrition was not responsible for *Pythium* blight control. Subdue Maxx provided significantly better control than all treatments on creeping bentgrass in 2005, but did not differ from the phosphonate fungicides in 2004.

Trials conducted in the *Pythium* chamber represent a severe test for fungicide performance, and are better for measuring rela-

tive differences among fungicides than for measuring the actual degree of control in the field.

Anthracnose and putting green quality trials

In 2004 and 2005, we conducted field trials on a putting green to determine whether active ingredient and formulation of different phosphonate fungicides influence control of anthracnose basal rot and putting green quality. The trials were conducted on an 8-year-old mixed stand of Providence creeping bentgrass and annual bluegrass (*Poa annua*) growing in an 80:20 root-zone mix and maintained as a putting green. A minimal amount of nitrogen was applied to the trial area to encourage development of anthracnose. Treatments (Table 2) were similar to those in the *Pythium* blight trial, except that there was no Subdue Maxx treatment. All treatments were applied every two weeks beginning on May 21 and ending Aug. 13 in 2004; and beginning May 4 and ending July 29, 2005, for a total of seven applications in each year. Anthracnose disease ratings were assessed visually using a 0 to 10 scale, with 10 indicating severe disease and 0 indicating no disease. Because very little disease was evident on the test area in 2004, only results from 2005 are discussed in this article. Putting green quality was rated every two weeks, just before treatment application, on a scale of 0 to 10, with 10 indicating excellent turf quality and 0 indicating very poor quality.

Results

Anthracnose symptoms developed rapidly on the test site during early July 2005, and the test was evaluated on July 5 after five treatment applications had been made. None of the phosphonate fungicides completely controlled anthracnose, but the Chipco Signature and potassium phosphite standard treatments had significantly less disease than the untreated control. Chipco Signature performed better than Aliette (both were applied at the same rate of fosetyl-Al), indicating that the formulation of Chipco Signature may be enhancing disease control. The potassium phosphite standard showed significantly less disease than the untreated control, indicating that this compound *may* have some benefit in suppressing anthracnose under certain conditions. With respect to anthracnose, none of the other treatments differed significantly from the untreated control. Although these results are interesting, we would like to point out that data from anthracnose trials often vary from region to region and from year to year. Nevertheless, we now have justification for conducting more extensive anthracnose trials with phosphonate fungicides.

The results for putting green quality were similar to the anthracnose results, with the Chipco Signature treatment providing slightly better quality than other treatments on most rating dates during 2004 and 2005 (Figure 5). The other phosphonate treatments usually provided better putting green quality than the potassium phosphate treatment and

ANTHRACNOSE VS. PHOSPHONATE

Treatment	Rate/1,000 square feet	Rate/hectare	Disease severity (0-10) [†]
			July 5, 2005
Control	—	—	5.5 ab [‡]
Potassium phosphate	4.0 ounces	12.2 kilograms	6.3 a
Alude	7.4 fluid ounces	23.6 liters	4.5 bc
Aliette	5.7 ounces	17.4 kilograms	4.5 bc
Potassium phosphite standard	43.6 fluid ounces	138.8 liters	3.5 cd
Chipco Signature	5.7 ounces	17.4 kilograms	2.0 d

[†]Anthracnose basal rot disease severity ratings based on a 0-10 scale, where 0 = no disease and 10 = severe disease symptoms.

[‡]Data means within the same column that are followed by the same letter are not significantly different from one another.

Table 2. Treatment, application rate and anthracnose basal rot disease-severity ratings for the 2005 anthracnose phosphonate fungicide trial. Five treatment applications were made at two-week intervals before the July 5 rating date.

RESEARCH

the untreated control during both years, but the response was not as strong as the response to Chipco Signature.

Conclusions

The objectives of our study were to determine whether products made with potassium phosphite or fosetyl-Al provide similar control of *Pythium* blight and anthracnose basal rot, as well as enhanced putting green quality, when applied at equivalent rates of phosphorous acid. Although levels of overall *Pythium* blight control varied between 2004 and 2005, no differences were found among phosphonate treatments in either year, regardless of active ingredient or formulation. Chipco Signature and the potassium phosphite standard provided some control of anthracnose, but complete control was not achieved.

Chipco Signature performed better than Aliette, a product containing fosetyl-Al, which was applied at the same rate of active ingredient as Chipco Signature. Based on this observation, we concluded that the formulation of Chipco Signature played an important role in suppressing this disease. It is not surprising that most phosphonate products did not have a pronounced effect on anthracnose, given that our laboratory studies (not discussed in this article) show that

THE RESEARCH

says . . .

- **We compared products** made with potassium phosphite or fosetyl-Al to determine whether they provide similar control of *Pythium* blight and anthracnose basal rot when applied at equivalent rates of phosphorous acid and to determine whether product formulation influences disease control.
- **Products with phosphites** and fosetyl-Al as active ingredients provided similar control of *Pythium* blight, and formulation of individual products did not appear to have any effect.
- **The potassium phosphate** treatment had no effect on *Pythium* blight control.
- **The Chipco Signature** and potassium phosphite standard treatments had significantly less anthracnose than the untreated control. We concluded that the formulation of Chipco Signature is a factor in anthracnose control.
- **Chipco Signature provided** slightly better putting green quality than all other phosphonate treatments in 2004 and 2005.

the phosphorous acid does not have a strong inhibitory effect on the causal pathogen, *Colletotrichum graminicola*.

Chipco Signature also provided slightly better putting green quality than all other phosphonate treatments in 2004 and 2005. Although the improvement in putting green quality may have been partly due to anthracnose control, Chipco Signature plots were greener and appeared healthier (fewer brown and thin areas) than other treatments on most ratings dates. The enhanced green-up

may have been partially a result of residual pigment from the Chipco Signature formulation; however, we attempted to minimize this effect by taking ratings two weeks after treatments were applied.

Other phosphonate fungicides provided improved putting green quality at certain times during the test when compared to the control, but not as much as Chipco Signature. Currently, we are unsure of why phosphonate fungicides improve putting green quality. Quality improvement does not appear to be a phosphorus nutrition effect, but may be partially due to a reduction of minor pathogens present in putting green turf. More-detailed research may shed light on how some phosphonate fungicides improve turf quality, and provide insights into the environmental and management conditions under which this may occur.

Funding

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Acknowledgments

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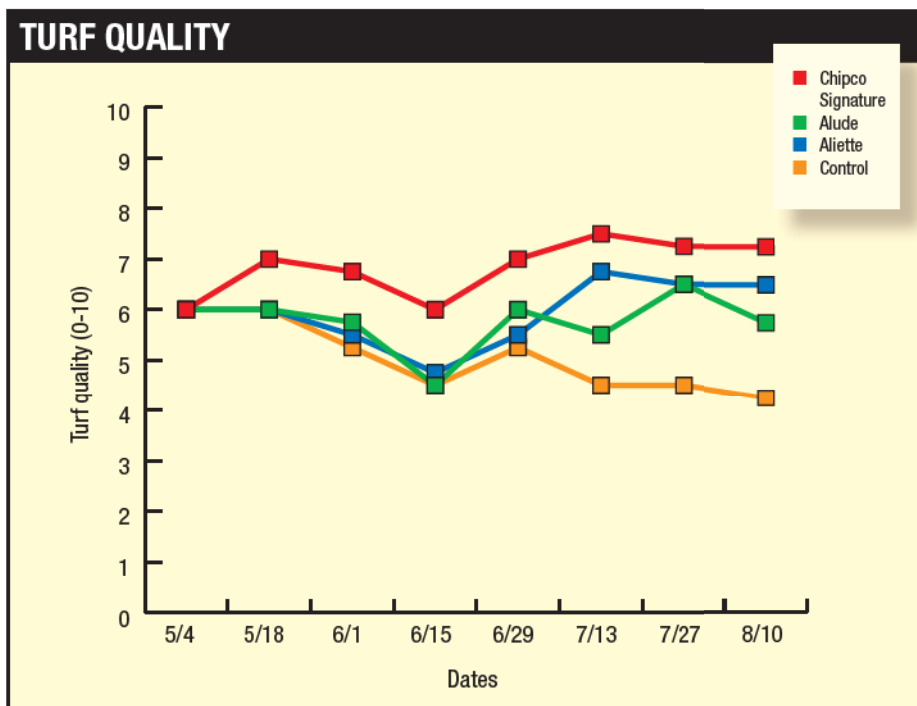


Figure 5. Turf-quality ratings of a creeping bentgrass/annual bluegrass putting green with an untreated control and plots treated with Aliette, Alude and Chipco Signature. Turf quality was rated on a scale of 0-10, where 10 was the highest-quality turf.

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The Impact of Various Tank-mixtures of Fungicide, Plant Growth Regulators and Phosphite Fertilizers on Potential Phytotoxicity, Turfgrass Quality and Dollar Spot Control



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Objective: Golf course superintendents routinely apply greater than one plant protection material in a tank-mix during summer months to fine turf areas. Tank-mixes are utilized because superintendents can apply protection materials for more than one disease at one time or can apply a plant growth regulator along with a fungicide or a fertilizer. Sometimes, a higher than normal level of tip-burn (phytotoxicity, chlorotic tissue) may be observed in the days following the application. Little data or field research results are available on the impact of mixing fungicides, plant growth regulators, and phosphite fertilizers together on warm-to-hot and sunny days through the summer months for their effects on the sward of turf. Also, there have been field reports of various phosphite fertilizers causing unacceptable levels of tip-burn when applied under various environmental conditions. There is little research conducted that has evaluated ‘worst-case’ scenarios for both of the aforementioned non-target effects. Therefore, the objective of this trial was to gain a better understanding of the potential for various tank-mix combinations to cause non-target effects to the creeping bentgrass fairway height turf.

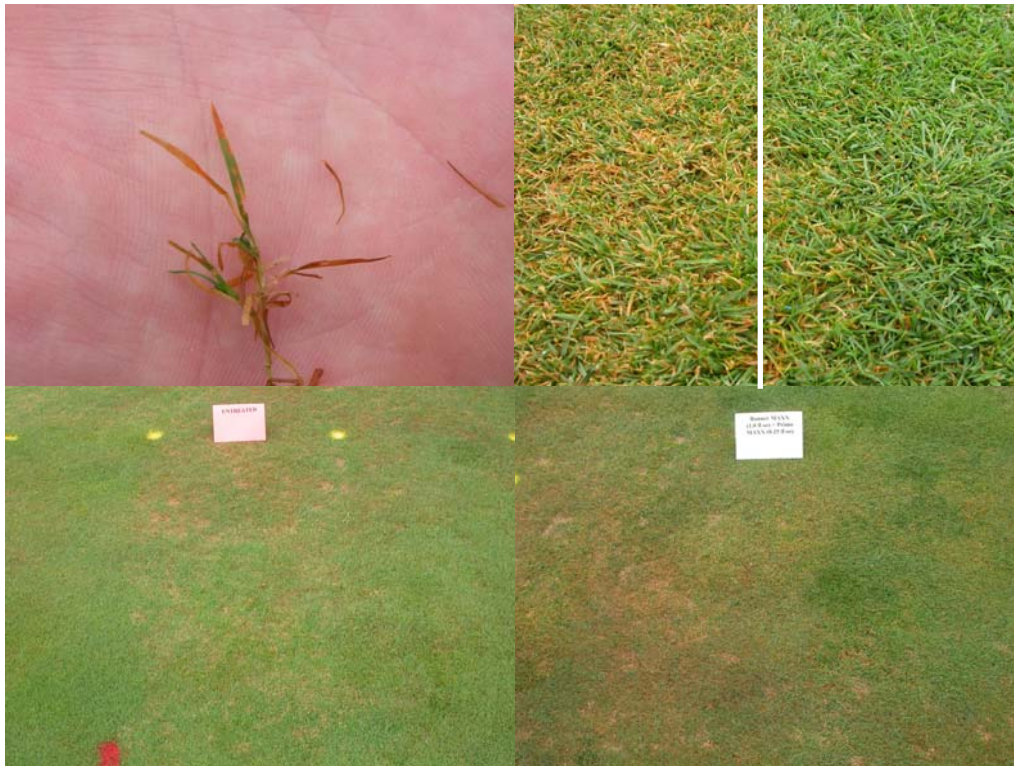
Material and Methods: This trial was conducted on the driving range fairway on Bellewood Golf Club, located in Pottstown, PA. The stand consists of ‘PennTrio’ creeping bentgrass (with minor amounts of perennial ryegrass) mowed at 0.5 inches. This area receives a lot of traffic from the ball pickers and routine range maintenance. Irrigation was present in the trial area, however, this area was placed under minor drought stress due to infrequent rainfall events throughout the entire year. This turf should be considered under traffic and minor drought stress. The soil is a native ‘clay-loam’ with a pH of 6.4. Individual plot size was 2.5 x 6 ft and treatments were arranged in a randomized complete block with four replications.

Treatments were all applied on 17 and 30 July and 13 August 2007. Treatments were applied with a CO₂ pressurized (38 psi) sprayer equipped with a single flat-fan (8004) nozzle, and calibrated to deliver 1.0 gal water per 1000 ft². All applications were made mid-morning typically

between 0900 to 1100 hours to a canopy with partial dew present. No irrigation was applied to the area prior to or following applications and all treatments were allowed to dry.

Two phosphite fertilizers each with different analysis were included in the tank-mixture treatments this trial. The Starphite product was applied at 2.0 fl oz/1000ft². This product analysis was a 2-40-16 containing 40% phosphite. The PK Plus was applied at 6.0 fl oz/1000ft². The analysis for this product is 3-21-18. The Plant Food Phosphite 30 was applied at 3.0 and 6.0 fl oz/1000ft² and this product has an analysis of 0-30-27.

Dollar spot was active at the initiation of the trial and it was assessed visually on a linear 0 to 100% scale; where 0 = entire plot area green and healthy, and 100 = entire plot area blighted. Phytotoxicity was observed throughout the trial and was rated on a 0 to 5 scale where 2.0= unacceptable tip-burn with browning to the leaf and 5.0= death or complete browning of the canopy. All tip-burn was observed to the upper parts of the leaves and no injury was observed to the lower leaves and crowns. Turfgrass quality was rated on a 0 to 10 scale with 7.5= the minimal acceptable quality for a golf course fairway and 10= optimal greenness, density, and overall quality. Data were subjected to analysis of variance (ANOVA) using SAS MIXED procedure and the Fisher's LSD test ($P \leq 0.05$).



Results:

Creeping Bentgrass Injury

Treatments were first applied on 17 July when the daily high temperature was 89°F and the sun was abundant (Figure 1). By 20 July, significant tip burn (rated as phytotoxicity) was observed in some of the treated plots. Similar trends were observed on every rating date and should be considered constant. Throughout this trial, the highest level of injury and significantly different

from all other treatments was observed in plots treated with Revolution + Trimmit + Headway and Revolution + Trimmit + PKplus. It is likely that the three way combination caused significant tip-burn due to the fact that they should have be watered-in and off of the upper leaf canopy.

The second highest level of injury was observed in plots treated with Banner MAXX + Primo MAXX (1.0-1.9) and Heritage TL + Primo MAXX (1.8-2.3), followed by Headway + Primo (0.9-1.9). All three of these fungicides (Heritage TL, Banner MAXX, and Headway) are formulated similar. On the first rating date, the combination of Instrata + Primo MAXX caused less injury than the aforementioned fungicides, however, the level become equal by the 6 August rating date.

The combinations of these aforementioned fungicides with Trimmit did not cause significant tip burn throughout the entire trial.

All of the fungicide + Phosphite fertilizer treatments (i.e. Banner MAXX + Starphite and Banner MAXX + PKplus, Headway + both phosphite fertilizers, Heritage TL + both phosphite fertilizers and Instrata + both phosphite fertilizers) generally caused none to low (0.0) levels of tip-burn on every rating date.

There were four combination treatments where a plant growth regulator (either Primo MAXX or Trimmit) was mixed with a phosphite fertilizer. Primo MAXX + a phosphite fertilizer generally caused minor levels of tip-burn, which was significantly higher than Trimmit + a phosphite fertilizer. On the first three rating dates, no differences among Primo MAXX + Starphite and Primo MAXX + PKplus was observed, however on the 16 August rating date (3 days following the last application) it appeared that the tank-mix of PK Plus with Primo MAXX (0.7), caused a higher level of injury, when compared to Primo MAXX + Starphite (0.3)

PK plus applied at 12.0 fl oz/1000ft² did cause significant injury following the second application of materials (0.8-2.0). It should be important to note, that this rate was double the labeled rate. This treatment was included to simulate an overlap or mis-application with this product.

Four phosphite-alone at labeled rate (Plant Food Phosphite 30 at 3.0 and 6.0 fl oz/1000ft² and Starphite and PK Plus), treatments were included and all of these treatments generally caused low and acceptable levels of injury (less than 0.3).

By 24 August, most of the injury that had been previously observed was gone. This was 11 days since the last application, however, the average ambient daily air temperature significantly decreased following that application. Also, some much needed rainfall occurred in the second week of August which took stress off of the area.

Dollar spot Control

Dollar spot severity was rated four times following the initiation of this trial. Generally, all treated plots had less dollar spot blighting when compared to the untreated control. Dollar spot was active when the trial was started; however, the blighting did worsen in the untreated plots over the course of this trial. On 20 July (three days after first application), few distinct differences were observed among treatments.

By 27 July, however, all plots treated with combinations including: Banner MAXX, Headway, and Instrata were dollar spot free. One interesting observation was that the tank-mix of Heritage TL with Primo MAXX and Trimmit provided complete dollar spot control, which was significant better than the tank-mixtures of Heritage TL with the phosphite fertilizers. Both of the plant growth regulators combined with the phosphite fertilizers provided dollar spot suppression (1.8-2.0% plot area blighted) and no significant differences were observed. In general, all plots

treated with a phosphite fertilizer-alone had less dollar spot blighting when compared to the untreated (14.5% plot area blighted).

By 6 August, dollar spot pressure became generally severe and 22.0% plot area blighted was observed in the untreated plots. On 6 and 16 August, a similar trend was observed as was on 27 July. All plots treated with Banner MAXX, Headway, and Instrata were dollar spot free. Plots treated with Heritage TL + a PGR, were also, disease-free and equal to the aforementioned fungicides. Trimmit + a phosphite fertilizer (1.0-1.2% plot area blighted) provided better dollar spot suppression when compared to Primo MAXX + a phosphite fertilizer (3.0% plot area blighted). All of the phosphite fertilizer-alone treatments did provided dollar spot suppression, when compared to the untreated control, however, the level of suppression (i.e. control) was significantly less than most combination treatments and all fungicide treated plots.

Turfgrass Quality:

The largest factor affecting overall quality was the injury observed. Treatments that did not cause significant injury had the highest quality throughout the entire trial. On 20 July, the highest level of quality was observed in plots treated with Headway TL + Starphite. Also, on 20 July, equal levels of quality were observed in plots treated with Banner MAXX + both phosphites, Headway + PK plus, Instrata + both phosphites, and Plant Food Phosphite 29. Plots treated with PK Plus-alone, both of the three way mixes, and Primo + both phosphites had quality significantly less than the untreated control.

By 27 July, quality continued to worsen in plots where creeping bentgrass injury was observed. The highest level of quality was observed in plots treated with Banner MAXX + phosphites and Heritage TL + phosphites. The lowest level of quality was observed in the three way mixes and the lowest quality was observed in plots treated with Revolution + Trimmit + Headway (7.3) and this was significantly worse than the untreated control (8.0). Another important observation was that plots treated with phosphite fertilizers-alone (8.6-9.0) generally had significantly higher quality ratings, when compared to the untreated plots.

On both 6 and 16 August similar trends were observed. Very high levels (9.0-9.5) of quality were observed in all fungicide + phosphite treatments and could be due to the small and frequent applications of nitrogen in both of the phosphite products as well as other deficient nutrients. Poor (<7.9) to commercially unacceptable quality (< 7.5) was observed in plots treated with Banner MAXX + Primo, Headway + Primo, Heritage TL + Primo, and Instrata + Primo. Highly unacceptable (<7.0) turf quality was observed in plots treated with Trimmit + phosphites and Primo MAXX + phosphites, both of the three way mixes and PK plus applied at 12.0 fl oz/1000ft² and the untreated control. The poor quality observed in the untreated was due to the significant dollar spot blighting

Summary and Conclusions:

This trial was designed as a worse case scenario and high rates and relatively (13-14 days) tight intervals were used. We did not include all combinations of treatments or a materials applied individually. For example, Primo MAXX-alone was not included. It is also important to note that both the high rates of Trimit and Primo MAXX were used and it may have been better to use lower rates for the initial application to better understand how the turf would react. It was also a mid-season start and the phytotoxicity to the bentgrass may not have been as severe if the growth regulators were initially applied earlier in the spring. Future research evaluating the potential for injury and non-target effects of plant protection materials should be sure to include all possible combinations and single treatments. Two of the three applications occurred on days where the day time high was above 90°F. Future research could also investigate the factors involved with the tip-burn, such as formulation, air temperature, sunlight, and drought or wilt stress.

In recent years, there have been two significant changes to the chemical uses of golf course turf. With the introduction of phosphite fertilizer products into the turf market, their use has increased due to the fact that they can provide acceptable levels of *Pythium* blight control at a very cost effective alternatives to fungicides. Also, many superintendents have found the same benefits that were observed in this trial and that is there is an increase in color and quality from their application. The increase may be due to many factors, including the nitrogen, phosphite ion and potassium among other micronutrients.

Furthermore, the use of plant growth regulators (PGR) at higher than standard rates has become a frequent occurrence throughout my travels in the Mid-Atlantic. I see weekly applications of high rates of PGRs on many occurrences. Due to these frequent applications, the turf is never 'allowed' to be unregulated. The regulation of turf has been shown to be extremely beneficial in many previous research projects. However, issues may arise when the turf is under regulation and injury to the leaves is observed. It appears that when regulated turf is injured (i.e. tip-burn), more time is needed for the damage to 'grow-out'.

Data from this trial suggest that under certain environmental stresses, applying a PGR in combination with certain fungicides or formulations of fungicides as well as phosphite fertilizers, may cause minor to moderate levels of tip burn. One important issue to consider is that many turf areas are only foliar fertilized during the summer months. Any level of tip-burn may prevent a leaf from adsorbing the needed nutrients. Hence, the problem seems to worsen on an actual area.

It is important to note that this area of creeping bentgrass had never been treated with Primo or any other plant growth regulator prior to this study. Previous research has demonstrated that mid-season applications of plant growth regulators to turf that has never been treated with a plant growth regulator can cause unacceptable levels of plant injury. We may not have observed the same level of injury in the plots that received the Primo MAXX if the rate was lower or if the turf had been treated previously or earlier in the season with an early GA inhibitor plant growth regulator.

In this trial, the applications of phosphite fertilizers-alone at their suggested labeled rates generally caused no significant leaf injury. It has been understood in the industry that many of these phosphite fertilizer products differ in the salt content. Also, these products may significantly impact the pH of the spray solution when applied alone or when applied with a fungicide.

In order to produce the potassium phosphite ion, the phosphonic acid is mixed with an alkali salt to reduce the pH (Lanschot and Cook, 2007). An alkali salt is a basic, ionic salt of an alkali metal or alkaline earth metal element and typically potassium hydroxide (KOH) is used for making

agriculture grade phosphite products. Potassium phosphite, generally, is the labeled main ingredient in most phosphite fertilizer products used in turf. In the turfgrass plant, these products are converted to phosphite (PO^{-3}). Due to the many different products available to golf course superintendents, it would be extremely difficult to test all of them. In this trial, three were included alone and two were mixed with PGR and fungicides. Generally, these products provided 40-60% dollar spot control and improved creeping bentgrass color.

At some point golf course superintendents may observe some sort of tip burn from any product. Some ways to potentially reduce the severity of wide-spread injury may be to: 1.) make applications very early in the morning or late in the evening, while the sun is not as bright and while air temperatures may be cooler, 2.) syringe before and after applications to coat leaves with a film of water and help dissolve the applied materials and/or move off of the upper leaves (all of the injury in this trial was observed on leaves-see photo above), 3.) test out-of play areas prior to applications to large areas, such as fairways or important areas like greens, 4.) use of dyes to determine exact areas treatment and prevent overlaps-use of foam may not be as accurate due to wind can blow it, 5.) applying in higher spray volumes may help to reduce concentration of materials on upper leaves however, this may decrease effectiveness of contact fungicides, 6.) reduce stress from mechanical injury.

Once injury to the leaves is observed, it would be best to try to determine which products may be causing injury. In some circumstances, biostimulants (plant growth regulators) containing gibberellic acid may help to counteract the regulation. Gibberellin promotes growth and elongation of cells. Skipping mowing or raising mowing height may help to reduce some stresses. At that point it would also be prudent to cease applications of PGR or products that may have and regulation effect (some classes of fungicides). Also, a slight decrease in the mowing height for one mowing may help to remove the damage leaves. This, however, can also increase the plant stress and should not be recommended.

In conclusion, golf courses superintendents should consider many factors prior to applications of all plant protection materials. Under certain environmental conditions (i.e. new turf, bright sun, heat, drought or mechanical stress) non-target and negative effects can be observed. Generally, these can be avoided by timing and choosing the material(s) properly. Another important aspect of this trial was that it was conducted on fairway height creeping bentgrass. Injury or effects may have been worse if trial was done on a putting green or to a stand of *Poa annua*.

Table 1. **Phytotoxicity** observed following various materials and tank-mixes during the middle of the summer, 2007

Product 1 ^x	Rate Prod 1	Product 2	Rate Prod 2	20 Jul	27 Jul	6 Aug	16 Aug	24 Aug
				Turf Injury (0-5) ^z				
Banner MAXX	1.0 fl oz	Starphite	2.0 fl oz	0.0 g ^y	0.0 f	0.0 g	0.0 i	0.0 g
Banner MAXX	1.0 fl oz	PK plus	6.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Banner MAXX	1.0 fl oz	Primo	0.25 fl oz	1.9 b	1.0 b	1.9 b	1.8 d	0.4 f
Banner MAXX	1.0 fl oz	Trimmit	0.37 fl oz	0.7 e	0.4 e	1.1 e	0.9 e	0.5 ef
Headway	1.5 fl oz	Starphite	2.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Headway	1.5 fl oz	PK plus	6.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Headway	1.5 fl oz	Primo	0.25 fl oz	1.6 c	0.9 bc	1.7 c	1.9 cd	0.8 cd
Headway	1.5 fl oz	Trimmit	0.37 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Heritage TL	1.0 fl oz	Starphite	2.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Heritage TL	1.0 fl oz	PK plus	6.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Heritage TL	1.0 fl oz	Primo	0.25 fl oz	1.8 b	1.1 b	2.0 b	2.3 b	0.7 cde
Heritage TL	1.0 fl oz	Trimmit	0.37 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Instrata	3.0 fl oz	Starphite	2.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Instrata	3.0 fl oz	PK plus	6.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Instrata	3.0 fl oz	Primo	0.25 fl oz	1.7 c	0.9 cd	1.9 b	2.1 bc	0.6 def
Instrata	3.0 fl oz	Trimmit	0.37 fl oz	0.0 g	0.0 f	0.0 g	0.4 gh	0.0 g
Trimmit	0.37 fl oz	Starphite	2.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Trimmit	0.74 fl oz	PK plus	6.0 fl oz	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Primo MAXX	0.25 fl oz	Starphite	2.0 fl oz	0.1 gf	0.0 f	0.3 f	0.3 h	0.0 g
Primo MAXX	0.25 fl oz	PK plus	6.0 fl oz	0.2 f	0.0 f	0.2 f	0.7 ef	0.0 g
Plant Food Phosphite 30	3.0 fl oz	-	-	0.0 g	0.0 f	0.0 g	0.3 h	0.0 g
Plant Food Phosphite 30	6.0 fl oz	-	-	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Revolution + Trimmit + Headway	6.0 + 0.37 + 1.5	-	-	3.4 a	3.0 a	3.6 a	4.0 a	2.5 a
Revolution + Trimmit + PKplus	6.0 + 0.37 + 6.0	-	-	3.4 a	3.0 a	3.4 a	4.0 a	2.0 b
PKplus	6.0 fl oz	-	-	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
Starphite	2.0 fl oz	-	-	0.3 f	0.1 f	0.1 fg	0.6 fg	0.0 g
PKplus	12.0 fl oz	-	-	1.4 d	0.8 d	1.3 d	2.0 cd	0.8 c
Untreated		-	-	0.0 g	0.0 f	0.0 g	0.0 i	0.0 g
P>F	-	-	-	0.0001	0.0001	0.0001	0.0001	0.0001

^x All treatments were on 17 and 30 July and 13 August 2007.

^y Means in each column followed by different letters are significantly different ($P \leq 0.05$) according to the Fisher's protected least significant difference test.

^z Injury (as tip-burn) was rated on a 0-5 scale where 0.5= minor discoloration to the tip of leaves, and 2.0= extreme burning, chlorosis and should be considered unacceptable.

Table 2. Percent of plot area blighted with dollar spot as influenced by various applications, 2007

Product 1 ^x	Rate Prod 1	Product 2	Rate Prod 2	20 Jul	27 Jul	6 Aug	16 Aug
% blighted by <i>S. homoeocarpa</i> (0- 100) ^z							
Banner MAXX	1.0 fl oz	Starphite	2.0 fl oz	2.4 hij ^y	0.0 f	0.0 g	0.0 e
Banner MAXX	1.0 fl oz	PK plus	6.0 fl oz	3.1 f-j	0.0 f	0.0 g	0.0 e
Banner MAXX	1.0 fl oz	Primo	0.25 fl oz	2.8 g-i	0.0 f	0.0 g	0.0 e
Banner MAXX	1.0 fl oz	Trimmit	0.37 fl oz	1.7 j	0.0 f	0.0 g	0.0 e
Headway	1.5 fl oz	Starphite	2.0 fl oz	2.3 ij	0.0 f	0.0 g	0.0 e
Headway	1.5 fl oz	PK plus	6.0 fl oz	2.2 ij	0.0 f	0.0 g	0.0 e
Headway	1.5 fl oz	Primo	0.25 fl oz	2.2 ij	0.0 f	0.0 g	0.0 e
Headway	1.5 fl oz	Trimmit	0.37 fl oz	2.2 ij	0.0 f	0.0 g	0.0 e
Heritage TL	1.0 fl oz	Starphite	2.0 fl oz	2.2 f-i	2.4 de	1.1 gf	1.0 e
Heritage TL	1.0 fl oz	PK plus	6.0 fl oz	2.9 g-j	2.0 e	1.1 gf	1.0 e
Heritage TL	1.0 fl oz	Primo	0.25 fl oz	3.3 g-j	0.0 f	0.0 g	0.0 e
Heritage TL	1.0 fl oz	Trimmit	0.37 fl oz	3.9 d-h	0.0 f	0.0 g	0.0 e
Instrata	3.0 fl oz	Starphite	2.0 fl oz	3.2 f-j	0.0 f	0.0 g	0.0 e
Instrata	3.0 fl oz	PK plus	6.0 fl oz	3.6 e-i	0.0 f	0.0 g	0.0 e
Instrata	3.0 fl oz	Primo	0.25 fl oz	4.3 d-g	0.0 f	0.0 g	0.0 e
Instrata	3.0 fl oz	Trimmit	0.37 fl oz	3.8 e-i	0.0 f	0.0 g	0.0 e
Trimmit	0.37 fl oz	Starphite	2.0 fl oz	3.6 f-i	1.8 e	1.0 gf	1.2 e
Trimmit	0.74 fl oz	PK plus	6.0 fl oz	3.9 d-h	2.0 e	1.9 f	1.0 e
Primo MAXX	0.25 fl oz	Starphite	2.0 fl oz	3.5 f-i	2.0 e	1.7 f	3.0 d
Primo MAXX	0.25 fl oz	PK plus	6.0 fl oz	5.2 b-e	2.0 e	3.1 d	3.0 d
Plant Food Phosphite 30	3.0 fl oz	-	-	6.2 bc	7.7 b	6.0 c	6.4 c
Plant Food Phosphite 30	6.0 fl oz	-	-	6.0 bc	4.4 c	3.0 de	4.3 d
Revolution + Trimmit + Headway	6.0 + 0.37 + 1.5	-	-	2.7 g-j	0.0 f	0.0 g	0.0 e
Revolution + Trimmit + PKplus	6.0 + 0.37 + 6.0	-	-	5.5 bcd	1.5 e	2.2 def	4.3 d
PKplus	6.0 fl oz	-	-	6.0 bc	7.3 b	7.5 b	9.5 b
Starphite	2.0 fl oz	-	-	6.5 b	8.0 b	7.7 b	9.8 b
PKplus	12.0 fl oz	-	-	4.6 c-f	3.3 cd	3.0 de	6.0 c
Untreated	-	-	-	8.5 a	14.5 a	22.0 a	24.0 a
P>F	-	-	-	0.0001	0.0001	0.0001	0.0001

^x All treatments were on 17 and 30 July and 13 August 2007.

^y Means in each column followed by different letters are significantly different ($P \leq 0.05$) according to the Fisher's protected least significant difference test.

^z Percent of plot area blighted was visually assessed on a 0 to 100 scale, with 0= no dollar spot blighting and 100=entire plot area blighted.

Table 3. Turfgrass Quality as influenced by various applications, 2007

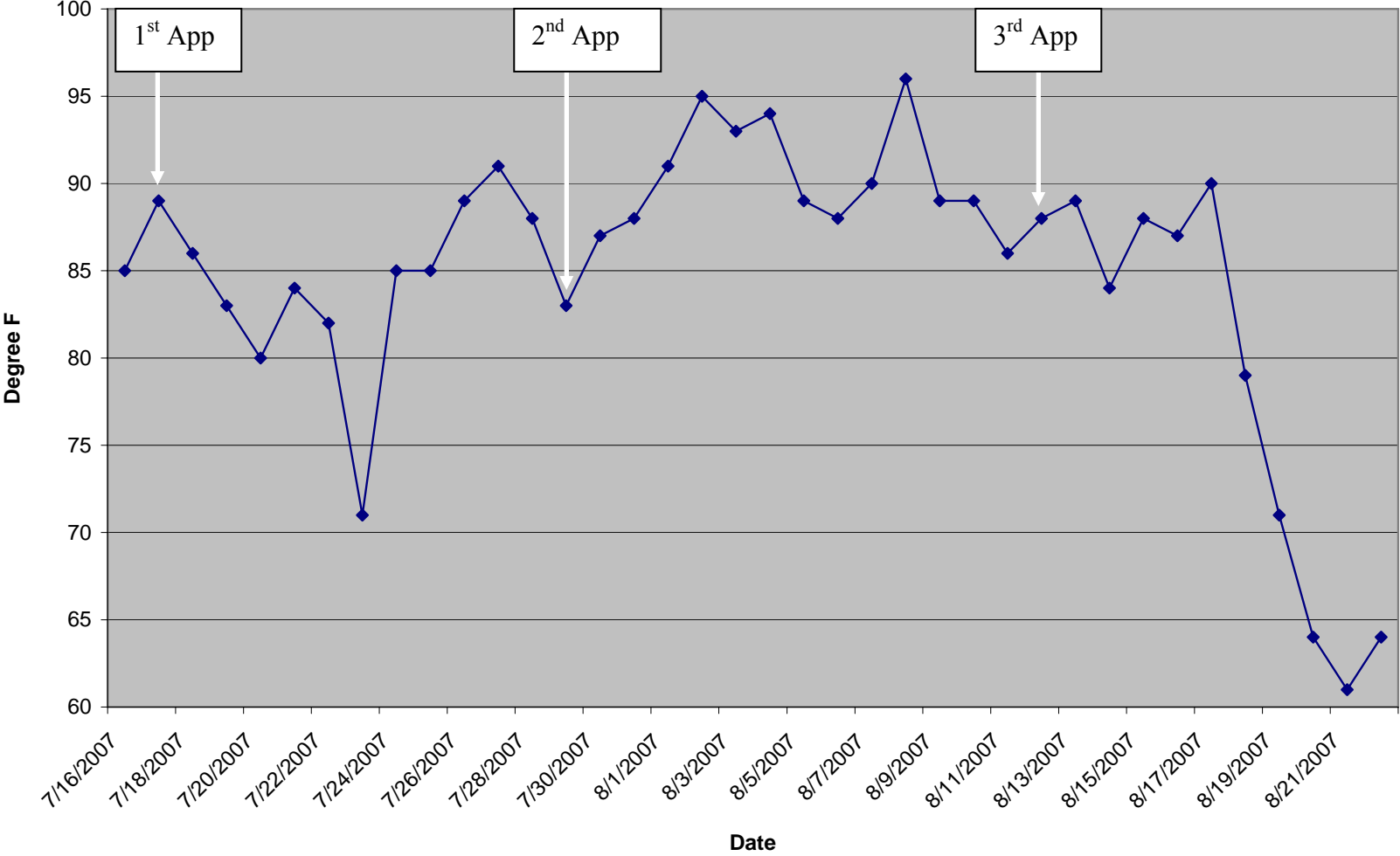
Product 1 ^x	Rate Prod 1	Product 2	Rate Prod 2	20 Jul	27 Jul	6 Aug	16 Aug
Quality (0-10) ^z							
Banner MAXX	1.0 fl oz	Starphite	2.0 fl oz	9.0 bcd ^y	9.1 a	9.4 a	9.5 a
Banner MAXX	1.0 fl oz	PK plus	6.0 fl oz	9.0 bcd	9.1 ab	9.3 ab	9.5 a
Banner MAXX	1.0 fl oz	Primo	0.25 fl oz	8.7 hi	8.4 d	7.9 g	7.5 f
Banner MAXX	1.0 fl oz	Trimmit	0.37 fl oz	8.9 de	9.0 b	8.2 f	8.0 e
Headway	1.5 fl oz	Starphite	2.0 fl oz	9.2 a	9.0 b	9.0 cd	9.2 c
Headway	1.5 fl oz	PK plus	6.0 fl oz	9.0 bcd	9.0 b	9.0 cd	9.3 bc
Headway	1.5 fl oz	Primo	0.25 fl oz	8.6 i	8.5 e	7.6 h	7.4 fg
Headway	1.5 fl oz	Trimmit	0.37 fl oz	8.9 ef	8.5 c	8.0 fg	8.0 e
Heritage TL	1.0 fl oz	Starphite	2.0 fl oz	9.0 cd	9.1 ab	9.3 ab	9.3 bc
Heritage TL	1.0 fl oz	PK plus	6.0 fl oz	8.8 g	7.9 fg	8.5 e	9.3 bc
Heritage TL	1.0 fl oz	Primo	0.25 fl oz	8.6 hi	8.2 e	7.3 ij	7.2 hi
Heritage TL	1.0 fl oz	Trimmit	0.37 fl oz	8.6 hi	8.5 c	8.0 fg	8.0 e
Instrata	3.0 fl oz	Starphite	2.0 fl oz	9.1 ab	8.9 b	9.2 bb	9.3 bc
Instrata	3.0 fl oz	PK plus	6.0 fl oz	9.0 bcd	9.0 b	9.2 abc	9.4 b
Instrata	3.0 fl oz	Primo	0.25 fl oz	8.7 h	8.1 ef	7.5 hi	7.3 gh
Instrata	3.0 fl oz	Trimmit	0.37 fl oz	8.8 fg	8.5 c	8.1 fg	8.1 e
Trimmit	0.37 fl oz	Starphite	2.0 fl oz	8.6 i	8.2 e	7.0 kl	7.0 jk
Trimmit	0.74 fl oz	PK plus	6.0 fl oz	8.5 jk	8.0 fg	7.0 kl	6.9 k
Primo MAXX	0.25 fl oz	Starphite	2.0 fl oz	8.4 kl	8.0 fg	6.8 l	7.1 ij
Primo MAXX	0.25 fl oz	PK plus	6.0 fl oz	8.4jlk	8.0 fg	7.0 kl	7.0 jk
Plant Food Phosphite 30	3.0 fl oz	-	-	8.8 g	8.6 c	8.0 fg	8.0 e
Plant Food Phosphite 30	6.0 fl oz	-	-	9.1 bc	9.0 b	9.0 cd	9.0 d
Revolution + Trimmit + Headway	6.0 + 0.37 + 1.5	-	-	8.0 jkl	7.3 i	6.1 m	5.0 l
Revolution + Trimmit + PKplus	6.0 + 0.37 + 6.0	-	-	8.3 m	7.5 h	6.0 m	5.0 l
PKplus	6.0 fl oz	-	-	8.8 g	8.6 c	8.8 d	8.0 e
Starphite	2.0 fl oz	-	-	8.8 g	8.6 c	8.8 d	8.0 e
PKplus	12.0 fl oz	-	-	8.3 m	7.8 g	7.2 jk	7.1 hi
Untreated	-	-	-	8.5 j	8.0 fg	7.6 h	7.1 hij
P>F	-	-	-	0.0001	0.0001	0.0001	0.0001

^x All treatments were on 17 and 30 July and 13 August 2007.

^y Means in each column followed by different letters are significantly different ($P \leq 0.05$) according to the Fisher's protected least significant difference test.

^z Turf quality was rated on a 0 to 10 scale with 7.5 being the minimal acceptable quality for a golf course fairway and 10= optimal playability, color and appearance.

Daytime High Temperatures, Pottstown PA 2007



Observations from “The Impact of Various Tank-mixtures of Fungicide, Plant Growth Regulators and Phosphite Fertilizers n Potential Phytotoxicity, Turfgrass Quality and Dollar Spot Control”

Table 1- Phytotoxicity

- Plant Food Phosphite 30 produced very low phytotoxicity when applied alone and compared to Griggs’ PKplus 3-21-18 and UAP Starphite 2-40-16. Plant Food Phosphite 30 is manufactured with virgin Phosphorous Acid and virgin potassium hydroxide which translates to higher turf safety.
- Potassium Phosphite products have systemic action in that they move into the leaf tissue, and move up and down in the plant via the xylem and phloem. (A good thing)
- **The Perfect Storm Scenario:** When tank mixing; especially with Growth Regulators, the Potassium Phosphite may carry other products into the plant. Research demonstrates that some Growth Regulators has some degree of phytotoxicity, especially during the first spray application of the season. In some cases, if sufficient water is not applied with the potassium phosphite spray tank mixture with growth regulators, the tank mix may increase the osmotic pressure within the cell walls and result in tissue damage, especially in dry, hot conditions. Generally, the first place an applicator may observe this condition is in the wheel tracks of the sprayer. This occurs because the blades of turf are lying down on the ground, creating greater surface area on the leaf blade versus blades of turf that are standing upright. These conditions, along with warm-to-hot and sunny days are caution conditions, especially if this is one of the first applications of the season with a growth regulator.
 - **What can you do?**
 - Make your first Growth Regulator application with just an Iron and Manganese tank mix.
 - When applying a potassium phosphite, pay attention to the amount of spray solution. Generally, apply a potassium phosphite at no higher than a 2% spray solution. For example, if applying 1.5 gallons (192 oz) of spray solution, apply no more than 3.84 oz of potassium phosphite.
 - Use a potassium phosphite that has demonstrated low phytotoxicity results, like the Plant Food Phosphite 30
 - When applying the Plant Food Phosphite 30 at 3 oz per 1,000, spray with a minimum of 1.2 gallons per 1,000 sq. ft.

Table 2- Dollar Spot

- This trial demonstrated that Potassium Phosphites can reduce the severity of dollar spot. These fertilizer products are not fungicide and do not claim to be one. Research has shown that potassium phosphites turn on a plants’ natural defense mechanism which creates a healthier plant. In this trial, Plant Food Phosphite 30 reduced the severity of dollar spot by 40-50% in comparison to the untreated area. Plant Food recommends that to control diseases, refer to an EPA labeled fungicide, and follow the directions carefully.