

Evaluation of Phosphonate Fungicides for Control of Anthracnose Basal Rot and Putting Green Quality

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Introduction

Phosphonate fungicides are used by golf course managers to control *Pythium* diseases, suppress anthracnose basal rot, alleviate summer stress, and improve turf quality. In many areas of the northeast, phosphonate products are applied at regular intervals throughout the summer as part of a putting green management program. Over a dozen phosphonate fungicides and fertilizers are currently available for use on golf courses. Although these products have similar active ingredients, they differ in trade name, formulation, label terminology, uses, and price. Understanding the different phosphonate products and how they perform in the field should help golf course managers choose the appropriate product for their particular need.

The objective of this study was to determine if active ingredient (potassium phosphite or fosetyl Al) and formulation of various phosphonate fungicides (Alude, Aliette, and Chipco Signature) provide similar control of anthracnose basal rot and influence the quality of a mixed annual bluegrass (*Poa annua* L.)/creeping bentgrass (*Agrostis stolonifera* L.) putting green when applied at equivalent rates of phosphorous acid (the active compound for controlling diseases).

Materials and Methods

This study was conducted on a research putting green at the Joseph Valentine Turfgrass Research Center, University Park, PA during 2004 and 2005. The putting green soil is a uniform sandy loam with a pH of 7.2, 138 lb Mehlich-3 P/A (69 ppm Mehlich-3 P), 0.07 meq K/100 g soil (28 ppm K), and a CEC of 6.2 meq/100 g soil. The turfgrass is an eight-yr-old mixed stand of 'Providence' creeping bentgrass (~70%) and annual bluegrass (~30%). The turf was mowed at 1/8 inch with a triplex greens mower six times per week during the growing season. Clippings were collected in baskets and removed from the site. The test area was fertilized with 2 lb N/1000 ft² as IBDU in Oct, 2003 and 2004, and 0.5 lb N/1000 ft² as IBDU in June, 2005. Curalan 50EG (vinclozolin, BASF Corp., Research Triangle Park, NC) was applied at 1.0 oz/1000 ft² to the test area to control dollar spot in Sep, 2004 (after the 2004 test was terminated) and Turfcide 10% Granular (pentachloronitrobenzene, Crompton Crop Protection, Middlebury, CT) was applied in Nov, 2004 at 10 lb/1000 ft² to prevent snow mold diseases. No fungicides were applied to the test area during spring and summer of 2004 and 2005, other than those used as treatments in the test.

2004 treatments: Two sets of treatments were included in the 2004 test. One set included commercial formulations of three phosphonate fungicides; Alude (Cleary Chemical Corp., Dayton, NJ), Aliette (Bayer Environmental Science, Montvale, NJ), and Chipco Signature (Bayer Environmental Science, Montvale, NJ); a 1.0 M solution of reagent-grade phosphorous acid (H_3PO_3) adjusted to a pH of 6.2 with 10.0 M potassium hydroxide (KOH); a solution of reagent-grade phosphoric acid (H_3PO_4) adjusted to a pH of 6.2 with 10.0 M potassium hydroxide; and an untreated control. The second set of treatments included each of the treatments in the first set combined with Curalan 50EG and a Curalan 50EG control. Curalan 50EG (1.0 oz/1000 ft²) was added to each phosphonate treatment in the second set of treatments to control dollar spot disease (phosphonate fungicides do not control dollar spot) because this disease will severely damage unprotected plots. Also, Curalan 50 EG has very little effect on anthracnose basal rot, and presumably would not greatly influence results of the test (B. Clarke, personal communication).

Dollar spot disease became problematic during late June in the treatments that did not contain Curalan 50EG; thus Curalan 50EG (1.0 oz/1000 ft²) was added to these treatments beginning with the 30 June, 2004 application and throughout the remainder of the test. Although this change did not affect anthracnose basal rot ratings (all disease severity data was collected before the 30 June application), it could have influenced quality data after 30 June.

2005 treatments: All treatments applied in the 2004 test were also applied in the 2005 test. In addition to these treatments, 3336F (thiophanate methyl, Cleary Chemical Corp., Dayton, NJ) was applied alone and in combination with Alude, Chipco Signature, and reagent-grade phosphorous acid/potassium hydroxide. Another set of treatments included all of the 3336F treatments combined with Curalan 50EG (Table 1).

Treatment rates: All phosphonate treatments (fungicides and the reagent-grade phosphorous acid/ potassium hydroxide treatment) in 2004 and 2005 were applied at equivalent amounts of phosphorous acid, based on phosphorous acid equivalents listed on the Alude label and according to the chemical formula and amount of fosetyl Al listed on the Aliette and Chipco Signature labels. The rate of phosphorous acid used in this study was based on the phosphorous acid equivalent of an intermediate product rate (5.7 oz/1000 ft²) listed on the Chipco Signature label for anthracnose diseases, and for summer stress complex on the Alude label. The rates of product and phosphorous acid for all phosphonate treatments, the reagent-grade phosphoric acid/potassium hydroxide, Curalan 50EG, and 3336F treatments are provided in Table 1.

The experimental design was a randomized complete block design with four replications. Plot size was 10 ft by 3 ft. In 2004, all treatments were applied every 14 d beginning on 21 May and ending 13 Aug for a total of seven applications. In 2005, all treatments were applied every 14 d beginning on 4 May and ending 29 July for a total of seven applications. Treatments were applied with a CO₂-powered backpack sprayer equipped

with a single boom fitted with an 11008E nozzle. Applications were made at 40 psi with a dilution rate equivalent to 2 gal H₂O/1000 ft².

Anthraxnose basal rot disease severity and turf quality ratings were made every 14 d, just prior to treatment applications. Disease severity was visually assessed on a scale of 0 to 10, with 10 indicating severe disease symptoms and 0 indicating no visible symptoms. Quality was assessed visually using a scale of 0 to 10, with 10 indicating excellent turf quality and 0 indicating extremely poor quality turf. Disease severity and quality data were subjected to analysis of variance and means were separated using Fisher's Protected Least Significant Difference Test at the 0.05 level of significance.

Results

Anthracnose basal rot control:

2004 results: Anthracnose basal rot symptoms were apparent in mid to late June, but symptoms did not become severe at any time during the summer. The only treatments that showed a noticeable reduction in disease symptoms compared to the untreated and Curalan 50 EG controls on both rating dates were Chipco Signature and Chipco Signature + Curalan 50EG (Table 1). The Alude + Curalan 50EG treatment showed less severe symptom development compared to the untreated control, Curalan 50EG control, and Alude treatment on 22 June, but not on 30 June, 2004.

2005 results: A severe infestation of anthracnose basal rot occurred in early July, 2005, and the trial was rated on 5 July. Of the phosphonate treatments with no Curalan 50EG or 3336F added, only Chipco Signature and the reagent-grade phosphorous acid/potassium hydroxide treatments showed a reduction in anthracnose basal rot severity relative to the untreated control (Table 1). The Curalan 50EG treatment did not reduce the severity of anthracnose basal rot symptoms when compared to the untreated control. However, all of the phosphonate/Curalan 50EG treatment combinations reduced anthracnose basal rot symptoms when compared to the untreated control. The 3336F treatment caused a slight, but significant, reduction in disease severity compared to the untreated control; and all phosphonate/3336F treatment combinations provided lower disease ratings than the 3336F treatment. Three-way combinations of phosphonates, Curalan EG50, and 3336F did not perform better with respect to anthracnose basal rot control than any of the phosphonate/Curalan 50EG or phosphonate/3336F treatments. All treatment combinations containing Chipco Signature (Chipco Signature + Curalan EG50, Chipco Signature + 3336F, and Chipco Signature + Curalan EG50 + 3336F) provided better control of anthracnose basal rot than all other treatment combinations. However, none of these Chipco Signature combination treatments provided better disease control than Chipco Signature alone.

Turfgrass quality:

Turf quality data in 2004 and 2005 revealed differences among treatments 14 d following the first application and on all subsequent rating dates (Table 2 and 3 and Fig. 1 - 6). Phosphonate treatments provided better quality than the untreated control on most rating dates (note that Curalan 50EG was added to these treatments beginning on 30 June, 2004 and throughout the remainder of the test due to dollar spot development). Although some statistically significant differences in turfgrass quality were noted among the Alette, Alude, and the reagent-grade phosphorous acid/potassium hydroxide treatments in both years of the study, numerical values were usually within a single whole unit, indicating that these differences were very subtle. These results indicate that phosphorous acid and fosetyl Al have similar effects on turf quality when applied at equivalent amounts of phosphorous acid. On about half of the rating rates, Chipco Signature produced higher quality ratings than the other phosphonate treatments. On eight of the 16 rating dates, Chipco Signature ranked higher in turfgrass quality than Alette (both were applied at the

same rate of fosetyl AI) suggesting that the formulation of Chipco Signature has a positive effect on turfgrass quality.

Conclusions:

Of the phosphonate fungicide treatments included in this test, Chipco Signature generally provided the best control of anthracnose basal rot. The fact that Chipco Signature and Aliette treatments contained the same amount of active ingredient (fosetyl AI) indicates that differences in formulation may account for improved anthracnose control with Chipco Signature. When applied alone, Alude did not control anthracnose basal rot; however, when it was applied with 3336F, control was improved over 3336F alone. We are not surprised that most phosphonate treatments did not have a pronounced effect on anthracnose basal rot, given that our *in vitro* studies showed that phosphorous acid does not have a strong inhibitory effect on the causal pathogen, *Colletotrichum graminicola*.

Phosphonate treatments generally produced better turf quality than the untreated control during both years of the test; and Chipco Signature tended to produce better quality than the other phosphonate treatments at certain times during the study. Although the improvement in turfgrass quality may have been partly due to anthracnose control, Chipco Signature plots were greener and appeared healthier (fewer brown and thin areas) than the other treatments on several rating 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. Currently, we are unsure why phosphonate fungicides improve turfgrass quality. Quality improvement does not appear to be due to a nutritional effect, but may be partially (or wholly) due to a reduction in minor pathogens present in putting green turf. More detailed research may shed light on how phosphonate fungicides improve turf quality, and provide insight into the environmental and management conditions under which this may occur.

Funding for this study was provided by the Pennsylvania Turfgrass Council, Cleary Chemical Corp., and Bayer Environmental Science

Table 1. Treatments, rates, and anthracnose basal rot disease severity ratings for 2004 and 2005 anthracnose basal rot phosphonate fungicide trial.

Treatment	Rate (oz /1000ft ²)	Disease Severity		
		----- 2004 -----		2005
		22 June	30 June	5 July
		----- (0-10) ^a -----		
Control	----	2.8 ab ^b	2.5 a	5.5 ab
Curalan 50EG	1.0 oz	2.8 ab	2.8 a	4.8 bc
H ₃ PO ₄ /KOH	4.0 oz	3.3 a	2.8 a	6.3 a
H ₃ PO ₃ /KOH	43.6 fl oz	2.5 bc	2.0 ab	3.5 def
Alude	7.4 fl oz	2.8 ab	2.0 ab	4.5 bcd
Aliette	5.7 oz	2.5 bc	2.5 a	4.5 bcd
Chipco Signature	5.7 oz	1.5 de	1.0 c	2.0 gh
H ₃ PO ₄ /KOH + Curalan	4.0 + 1.0	3.3 a	2.5 a	5.0 bc
H ₃ PO ₃ /KOH + Curalan	43.6 + 1.0	2.3 bc	2.0 ab	3.5 def
Alude + Curalan	7.4 + 1.0	2.0 cd	1.8 ab	3.5 def
Aliette + Curalan	5.7 + 1.0	2.5 bc	1.8 ab	3.5 def
Chipco Signature + Curalan	5.7 + 1.0	1.0 e	0.5 c	1.3 h
3336F	6.0 oz	---	---	4.0 cde
3336F + H ₃ PO ₃ /KOH	6.0 + 43.6	---	---	2.8 fg
3336F + Alude	6.0 + 7.4	---	---	2.8 fg
3336F + Chipco Signature	6.0 + 5.7	---	---	1.3 h
3336F + Curalan	6.0 + 1.0	---	---	3.5 def
3336F + Curalan + H ₃ PO ₃	6.0+1.0+43.6	---	---	3.0 efg
3336F+ Curalan + Alude	6.0+1.0+5.7	---	---	2.8 fg
3336F + Curalan + Signature	6.0+1.0+5.7	---	---	1.3 h

^a Anthracnose basal rot disease severity ratings based on a 0-10 scale, 0 = no disease and 10 = very severe disease symptoms.

^b Data means within the same column and followed by the same letter are not significantly different as determined by Fisher's Protected Least Significant Difference test at $P=0.05$.

Table 2. Treatments, rates, and quality ratings for the 2004 anthracnose phosphonate fungicide trial.

Treatment	Rate (oz/1000 ft ²)	Turf Quality							
		5/21	6/2	6/16	6/30	7/16	7/28	8/13	8/26
Control ^a	----	5.8 a ^c	5.3 cd	4.8 e	4.3 g	4.8 d	4.8 c	4.3 f	4.3 g
Curalan	1.0 oz	5.8 a	6.0 b	6.0 cd	6.0 cd	5.5 d	5.0 c	5.3 de	4.8 g
H ₃ PO ₄ /KOH ^a	4.0 oz	5.5 a	5.8 bc	5.8 d	5.0 f	5.3 d	5.5 c	4.8 ef	5.0 fg
H ₃ PO ₃ /KOH ^a	43.6 fl oz	6.0 a	6.0 b	6.5 bc	5.5 def	7.8 bc	7.8 ab	5.8 cd	6.3 cde
Alude ^a	7.4 fl oz	5.8 a	5.0 d	5.5 d	5.0 f	7.0 c	7.3 b	5.8 cd	5.8 ef
Aliette ^a	5.7 oz	6.0 a	6.0 b	6.5 bc	5.8 de	8.0 bc	7.3 b	6.3 abc	6.3 cde
Signature ^a	5.7 oz	5.8 a	6.0 b	7.8 a	6.8 ab	8.3 ab	7.8 ab	6.5 ab	7.3 ab
H ₃ PO ₄ /KOH + Curalan	4.0 + 1.0	5.5 a	5.8 bc	6.5 bc	5.3 ef	5.5 d	5.3 c	5.0 e	4.5 g
H ₃ PO ₃ /KOH + Curalan	43.6 + 1.0	5.5 a	6.3 a	6.8 b	6.8 ab	7.8 bc	7.8 ab	6.5 ab	6.8 bcd
Alude + Curalan	7.4 + 1.0	5.5 a	5.8 bc	6.8 b	6.5 bc	7.5 bc	7.8 ab	6.0 bc	6.0 de
Aliette + Curalan	5.7 + 1.0	5.5 a	6.0 b	6.8 b	6.5 bc	8.3 ab	8.5 a	6.3 abc	7.0 abc
Signature + Curalan	5.7 + 1.0	5.8 a	6.8 a	7.8 a	7.3 a	9.3 a	8.5 a	6.8 a	7.8 a

^a Dollar spot disease became problematic during late June in treatments that did not contain Curalan 50EG, thus Curalan 50EG (1.0 oz/1000 ft²) was added to these treatments beginning with the 30 June application and throughout the remainder of the test.

^b Turf quality ratings based on a 0-10 scale, 10 = excellent turf quality 0 = poor turf quality.

^c Data means within the same column and followed by the same letter are not significantly different as determined by Fisher's Protected Least Significant Difference test at $P=0.05$.

Table 3. Treatments, rates, and quality ratings for the 2005 anthracnose phosphonate fungicide trial.

Treatment	Rate (oz/1000ft ²)	Turf Quality							
		5/4	5/17	5/31	6/15	6/28	7/13	7/29	8/10
		----- (0-10) ^a -----							
Control	----	6.0 a ^b	6.0 c	5.3 de	4.5 fg	5.3 e	4.5 j	4.5 d	4.3 g
Curalan	1.0 oz	6.0 a	6.3 bc	5.5 cd	5.0 def	5.8 cd	5.3 hi	5.3 d	4.5 g
H ₃ PO ₄ /KOH	4.0 oz	6.0 a	6.0 c	5.0 e	4.8 efg	5.8 cd	4.3 j	5.0 d	4.0 g
H ₃ PO ₃ /KOH	43.6 fl oz	6.0 a	6.0 c	5.3 de	5.0 def	6.0 bc	6.8 cde	7.0 bc	6.5 cdef
Alude	7.4 fl oz	6.0 a	6.0 c	5.8 bc	4.5 fg	6.0 bc	5.5 gh	6.5 c	5.8 f
Aliette	5.7 oz	6.0 a	6.0 c	5.5 cd	4.8 efg	5.5 de	6.8 cde	6.5 c	6.5 cdef
Chipco Signature	5.7 oz	6.0 a	7.0 a	6.8 a	6.0 ab	7.0 a	7.5 ab	7.3 abc	7.3 abc
H ₃ PO ₄ + Curalan	4.0 + 1.0	6.0 a	6.3 bc	5.3 de	5.0 def	6.0 bc	4.8 ij	5.3 d	4.0 g
H ₃ PO ₃ + Curalan	43.6 + 1.0	6.0 a	6.0 c	5.5 cd	5.0 def	6.0 bc	6.5 def	6.8 bc	6.0 ef
Alude + Curalan	7.4 + 1.0	6.0 a	6.0 c	6.0 b	5.5 bcd	6.0 bc	6.8 cde	6.8 bc	6.0 ef
Aliette + Curalan	5.7 + 1.0	6.0 a	6.3 bc	6.0 b	4.8 efg	5.8 cd	6.3 ef	6.8 bc	6.3 def
Signature + H ₃ PO ₃	5.7 + 1.0	6.0 a	7.0 a	7.0 a	6.0 ab	7.0 a	6.8 cde	7.3 abc	7.5 ab
3336F	6.0 oz	6.0 a	6.0 c	5.8 bc	4.3 g	6.3 b	6.5 def	7.0 bc	5.8 f
3336F + H ₃ PO ₃	6.0 + 43.6	6.0 a	6.0 c	5.8 bc	5.3 cde	6.3 b	7.5 ab	7.3 abc	6.8 bcde
3336F + Alude	6.0 + 7.4	6.0 a	6.0 c	6.0 b	4.3 g	6.0 bc	7.0 bcd	7.5 ab	6.8 bcde
3336F+Signature	6.0 + 5.7	6.0 a	7.0 a	7.0 a	5.8 bc	7.0 a	7.5 ab	8.0 a	8.0 a
3336F + Curalan	6.0 + 1.0	6.0 a	6.0 c	6.0 b	4.5 fg	6.0 bc	6.0 fg	6.5 c	6.0 ef
3336F + Curalan + H ₃ PO ₃	6.0 + 1.0 + 43.6	6.0 a	6.3 bc	6.0 b	4.8 efg	6.0 bc	7.0 bcd	7.5 ab	7.0 bcd
3336F + Curalan + Alude	6.0+1.0+7.4	6.0 a	6.5 b	6.0 b	4.3 g	6.0 bc	7.3 bc	7.0 bc	7.0 bcd
3336F + Curalan + Signature	6.0+1.0+5.7	6.0 a	7.0 a	7.0 a	6.5 a	7.0 a	8.0 a	8.0 a	8.0 a

^a Turf quality ratings based on a 0-10 scale, 10 = excellent turf quality 0 = poor turf quality.

^b Data means within the same column and followed by the same letter are not significantly different as determined by Fisher's Protected Least Significant Difference test at $P=0.05$.

Fig. 1. Influence of Chipco Signature, Alude, and the untreated control on putting green turf quality during 2004. Vertical bars indicate the Fisher's protected LSD value at $P = 0.05$. Lack of vertical bars indicates no significant differences between two treatments were detected on that rating date.

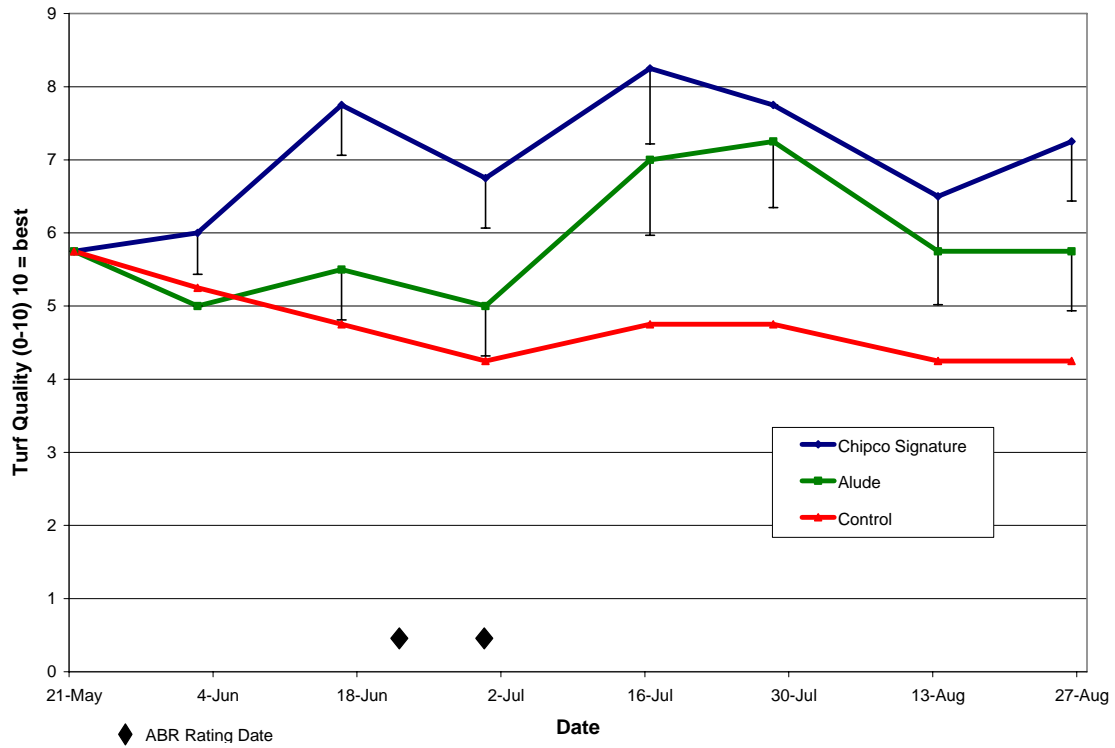


Fig. 2. Influence of the phosphorous acid/potassium hydroxide standard (H_3PO_3/KOH), Alude, and the untreated control on putting green turf quality during 2004. Vertical bars indicate the Fisher's protected LSD value at $P = 0.05$. Lack of vertical bars indicates no significant differences between two treatments were detected on that rating date.

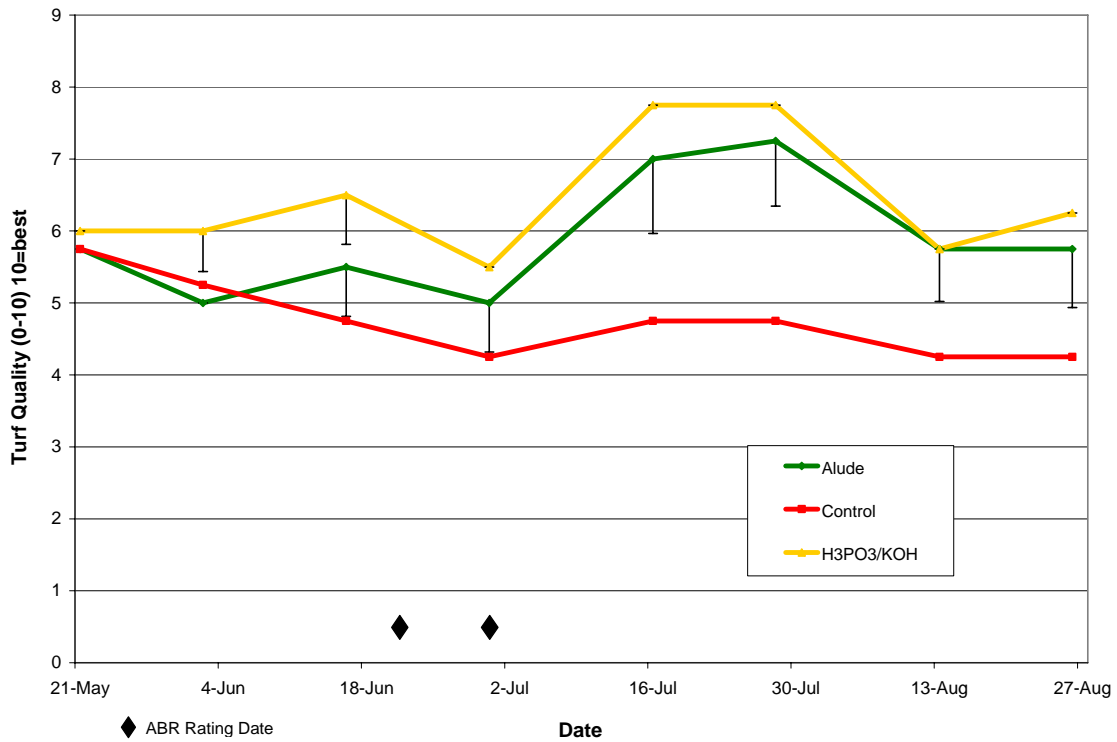


Fig. 3. Influence of the Chipco Signature, Aliette, and the untreated control on putting green turf quality during 2004. Vertical bars indicate the Fisher's protected LSD value at $P = 0.05$. Lack of vertical bars indicates no significant differences between two treatments were detected on that rating date.

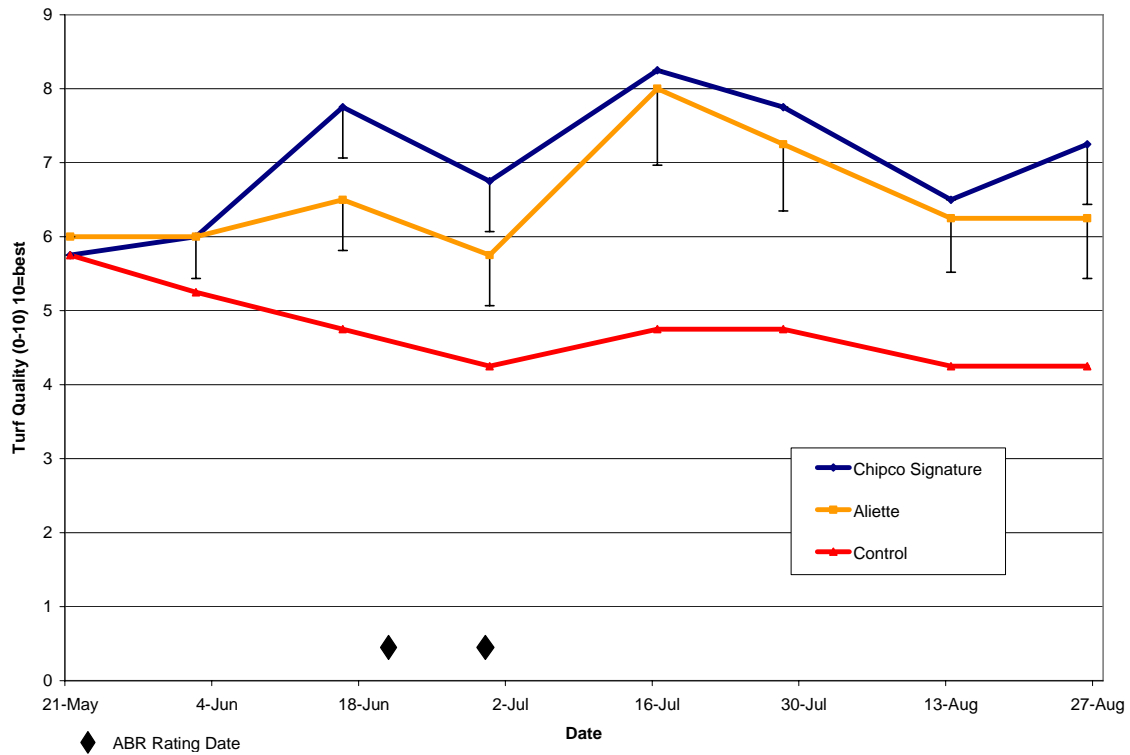


Fig. 4. Influence of Chipco Signature, Alude, and the untreated control on putting green turf quality during 2005. Vertical bars indicate the Fisher's protected LSD value at $P = 0.05$. Lack of vertical bars indicates no significant differences between two treatments were detected on that rating date.

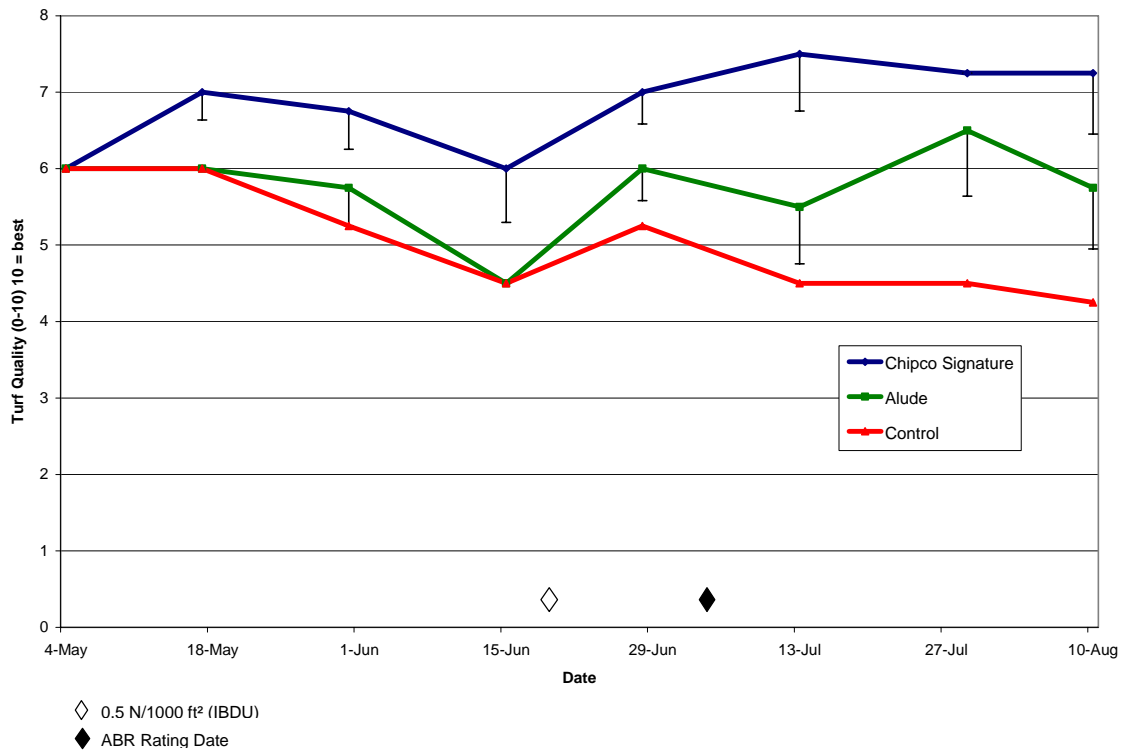


Fig. 5. Influence of the phosphorous acid/potassium hydroxide standard (H_3PO_3/KOH), Alude, and the untreated control on putting green turf quality during 2005. Vertical bars indicate the Fisher's protected LSD value at $P = 0.05$. Lack of vertical bars indicates no significant differences between two treatments were detected on that rating date.

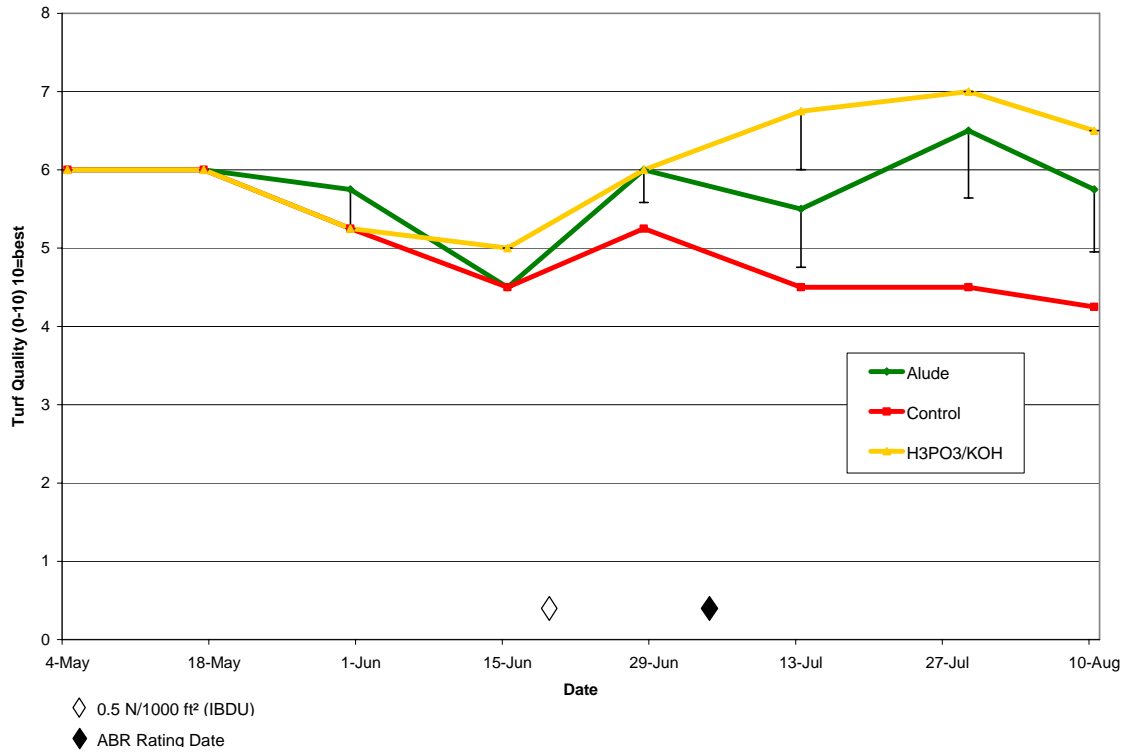


Fig. 6. Influence of Chipco Signature, Alette, and the untreated control on putting green turf quality during 2005. Vertical bars indicate the Fisher's protected LSD value at $P = 0.05$. Lack of vertical bars indicates no significant differences between two treatments were detected on that rating date.

