ABSTRACT

Phosphorus Fertility and the Physiological Response of Creeping Bentgrass and Annual Bluegrass

Creeping bentgrass (*Agrostis stolonifera*) is the preferred turfgrass species for golf course putting greens because of its high shoot density and tolerance for low mowing, Annual bluegrass (*Poa annua*) is another grass tolerant of low mowing and is a major invasive weed in putting greens. This research project was performed to evaluate possible physiological differences between the two grasses with respect to phosphorus uptake. This greenhouse experiment examined the two species of grass grown in two different sand types using four different phosphorus treatments. Clippings, shoots, and roots were compared based on dry weight and tissue concentrations for phosphorus. The readily available phosphorus treatments showed increased root mass, clipping yield and greater turfgrass quality than the less available phosphorus treatments. Differences between grass types across the various P levels were not consistently significant. This study suggests that the manipulation of soil P levels may not be an effective strategy to minimize annual bluegrass invasion as has previously been suggested.

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COVER SHEET

TITLE: _Phosphorus Fertility and the Physiological Response of Creeping Bentgrass and Annual Bluegrass_____________

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Abstract

Creeping bentgrass (*Agrostis stolonifera*) is the preferred turfgrass species for golf course putting greens because of its high shoot density and tolerance for low mowing which results in a smooth, fast playing surface. Annual bluegrass (*Poa annua*) is another grass tolerant of low mowing and is a major invasive weed in creeping bentgrass putting greens. This research project was performed to evaluate possible physiological differences between the two grasses with respect to phosphorus uptake. This greenhouse experiment examined the two species of grass grown in two different sand types using four different phosphorus treatments. The treatments were chosen to represent different forms of phosphorus with varying degrees of availability. Different soils were used to explore how differences in root zone mineralogy affected phosphorus availability. Forty-two plants were established from seed and evaluated over a ten-week period. Clippings, shoots, and roots were compared based on dry weight and tissue concentrations for phosphorus. The readily available phosphorus treatments showed increased root mass, clipping yield and greater turfgrass quality than the less available phosphorus treatments regardless of grass type. Differences between grass types across the various P levels were not consistently significant. The different root zones exhibited little effect on quality. This study suggests that the manipulation of soil P levels may not be an effective strategy to minimize annual bluegrass invasion as has previously been suggested.

Introduction

Annual bluegrass is undesirable to many turfgrass managers because of its unaesthetic light green color, abundant seed head production, and low tolerance to heat and cold stress. Low stress tolerance of annual bluegrass results in increased inputs of pesticides, nutrients, and water in maintenance (Vargas, 2004). Furthermore, after the weed invades and succumbs to stress, the dead patches of grass are unsightly and difficult to re-establish. Several products have been developed over the last decade with the promise of controlling the weed, although efficacy is inconsistent and side effects can be unsightly (Higgins, 2003). Depending on the year, the location, and the tolerance for the weed, controlling or maintaining annual bluegrass can be a large economic burden for the turf manager.

With increasing regulatory and social pressure to decrease the use of pesticides, turfgrass managers attempting to exclude annual bluegrass from their putting greens will be forced to consider non-chemical approaches. One possible non-chemical method is to take advantage of ecological differences between the two grasses. Results from previous research suggest that annual bluegrass has a higher phosphorus requirement than creeping bentgrass (Varco and Sartain, 1986; Goss et al., 1975). Creeping bentgrass may be able to thrive in low phosphorus conditions due in part to its voracious rooting and uptake mechanisms (Paré et al., 2006). If this is true, keeping annual bluegrass invasion to a minimum may be as simple as maintaining extremely low soil P availability.

The objective of this study was to compare the growth and phosphorus uptake differences between creeping bentgrass and annual bluegrass across a wide range of available phosphorus levels in an attempt to identify critical soil levels where creeping bentgrass can survive but annual bluegrass cannot. This research is particularly important for the golf course setting, where creeping bentgrass putting greens are established on sand-based root zones. If creeping bentgrass germination and growth is not inhibited at very low soil P levels, and annual bluegrass growth is, turfgrass managers would have an invaluable tool for controlling annual bluegrass establishment on newly constructed putting greens. This would result in fewer chemicals needed in an attempt to control annual bluegrass, as well as decreased amounts of pesticides, fertilizers, and water needed to maintain the grass after it is established. Controlling annual bluegrass would also improve the playability and aesthetics of the golf course.

Materials and Methods

Treatment selection and establishment

The popular G-6 variety of creeping bentgrass was selected along with a variety of annual bluegrass from the Pennsylvania State University breeding program. These varieties were chosen to closely resemble the grasses that are being grown in the field. Two different soils were also chosen to examine possible differences in plant responses as a result of different root zone mineralogy. One of the sands used was derived from dolomite while the other was a quartz-based sand. The quartz sand was a useful control medium for this research because it is completely inert of organic matter and nutrients. The dolomitic soil used was a subsoil found in the southwest region of Wisconsin in Iowa and Lafayette counties. The subsoil contained no organic matter and had 8% total clay content. The pH was 8.2 and the CEC was relatively high (Table 2). Four different fertility treatments were chosen and applied equally to attempt to gain a better understanding on the different grasses' ability for taking up different sources of phosphorus. Starter fertilizer (14-28-12) and struvite (6-30-0) were used to represent readily available sources of phosphorus. Struvite, $MgNH_4PO_4 \cdot 6H_2O$, is waste product formed during wastewater treatment. We have chosen to include struvite in this research to identify its usefulness as a turfgrass fertilizer. Struvite was added to the quartz sand root zones and not the dolomitic sand root zones because of a limited struvite supply. Fine grade apatite or rock phosphate (0-3-0) was used to represent a slowly available source of phosphorus, and in the control no phosphorus was added. Urea and potassium sulfate were added to the control, struvite, and rock phosphate treatments to keep the nitrogen and potassium levels consistent with starter fertilizer. Treatments are shown in Table 1. The experiment was evaluated for 56 days between seeding and harvest. The plants were established in four-inch diameter, four-inch depth pots and arranged in a completely randomized design, with three replications per treatment. Treatments were seeded at the recommended rate for each type of grass, 5 g/m^2 for creeping bentgrass and 20 g/m^2 for annual bluegrass. After two weeks of observing non-uniform seedling germination, the pots were interseeded to achieve a consistent density among the grasses.

Table 1. The fourteen treatments evaluated in this study, differing by root zone mineralogy, grass type, and fertility treatment.

Quartz sand			Dolomitic sand		
Creeping Bentgrass			Creeping Bentgrass		
	1	Starter fertilizer		9	Starter fertilizer
	2	Struvite		10	Rock P
	3	Rock P		11	Control
	4	Control	Annual Bluegrass		
Annual Bluegrass				12	Starter fertilizer
	5	Starter fertilizer		13	Rock P
	6	Struvite		14	Control
	7	Rock P			
	8	Control			

Table 2. Data from chemical analysis for soils evaluated in this study

Sand type	pH	Bulk Density	Cation Exchange Capacity (CEC)
		g cm^{-3}	cmol kg^{-1}
Dolomite	8.2	1.52	56.1
Quartz	7	1.52	0.0

Table 3. Particle size distribution of the two sand types used

Particle size	Quartz sand	Dolomitic sand
	%	%
Very fine gravel	0.00	4.12
Very course sand	0.00	3.51
Course sand	5.75	2.92
Medium sand	36.9	25.9
Fine sand	40.7	32.4
Very fine sand	14.2	26.3
Silt / clay	0.00	4.85

Fertilization and Irrigation

All treatments were incorporated into the soil at the rate of 10 g/m^2 phosphorus, and 5 g/m^2 for nitrogen and potassium. These rates are standard for putting green establishment. Urea (46-0-0) and K_2SO_4 (0-0-50) were used with the rock phosphate, struvite, and the control to keep N and K levels consistent with the starter fertilizer. A solution containing micronutrients was used to irrigate all of the pots during the fifth week of the experiment to eliminate the possibility of a micronutrient deficiency from developing during the study period. Additional fertilizer applications were made six and seven weeks following seeding each at half of the original application rate.. Pots were irrigated to the pre-determined pot moisture holding capacity by weight on two to three times each week to prevent drought and minimize nutrient leaching.

Biomass Measurements

Clippings were harvested with a scissors, weighed and dried at 60 ^{o}C two separate times during the experiment. Verdure (all biomass above the soil level) was harvested at the conclusion of the study. The verdure and two sets of clippings were ground with a mill and analyzed for phosphorus content by sulfuric acid digestion and analysis of neutralized solution by the ascorbic acid method (Murphy and Riley, 1962). The roots were separated from the verdure using a razor blade and then separated from the sand using a gentle flow of water over a 2 mm sieve. The roots were removed from the sieve with forceps, dried, weighed and placed in individual porcelain crucibles, which were heated to 500^{o}C for four hours. The roots disintegrated in the oven and the remaining sand was weighed again, with the difference between the two weights representing the weight of the root tissue.

Qualitative and Statistical analysis

Visual turfgrass quality and color ratings were taken two times during the eight week experiment. Ratings were recorded at four and six weeks after seeding, measured on a scale of 1-5. Quality ratings, clipping weights, verdure weight, root weight, and the tissue analysis of both clips and the verdure were statistically compared to find significant correlation between the fourteen treatments. A p-value of less than 0.05 was used to indicate statistical significance.

Results and Discussion

Yield

The combined mass of all collected above-ground biomass during the experiment was significantly greater for the starter fertilizer and struvite treatments compared to the control and rock phosphate trials. The rock phosphate treatments had greater clipping yield than the control pots in each of the harvests, although the difference was only statistically significant in the second clipping (Table 3). The quartz sand produced significantly higher yields than the dolomitic sand in the first and last harvest, but there was no difference in the second. The grass type was a statistically significant variable in only the second of the three harvests, where the creeping bentgrass yielded almost twice as much as annual bluegrass. The other two harvests averaged very similar yields between the grass types.

Table 3. Creeping bentgrass and annual bluegrass dry matter yield as affected by fertility treatment and root zone minerology

Treatment	Dry Matter Yield (g)			
	3/30/07	4/20/07	4/27/07	Total
Starter Fertilizer				
Quartz sand				
Creeping bentgrass	0.089 a	0.176 ab	0.816 ab	1.081 ab
Annual bluegrass	0.084 a	0.141 b	0.994 a	1.219 a
Dolomitic sand				
Creeping bentgrass	0.025 bc	0.214 a	0.566 cd	0.805 c
Annual bluegrass	0.017 bcd	0.145 b	0.581 cd	0.743 c
Struvite				
Quartz sand				
Creeping bentgrass	0.032 b	0.212 a	0.644 bc	0.888 bc
Annual bluegrass	0.007 cd	0.097 c	0.900 a	1.004 bc
Rock Phosphate				
Quartz sand				
Creeping bentgrass	0.003 d	0.077 c	0.334 ef	0.414 d
Annual bluegrass	0.004 d	0.020 d	0.406 de	0.430 d
Dolomitic sand				
Creeping bentgrass	0.009 cd	0.076 c	0.208 ef	0.293 de
Annual bluegrass	0.000 d	0.008 d	0.206 ef	0.214 de
Control				
Quartz sand				
Creeping bentgrass	0.000 d	0.016 d	0.144 f	0.160 e
Annual bluegrass	0.000 d	0.004 d	0.146 f	0.150 e
Dolomitic sand				
Creeping bentgrass	0.001 d	0.030 d	0.246 ef	0.277 de
Annual bluegrass	0.000 d	0.005 d	0.218 ef	0.223 de

These results demonstrate that both grasses produced more biomass when the struvite and commercial starter fertilizer was used. Previous researchers have suggested that creeping bentgrass can survive in low-P situations better than annual bluegrass. Under the conditions of this study we found evidence to support this hypothesis on one of three collection dates.

Quality

Both quality ratings were consistent in affirming that grass plants thrive with readily available phosphorus as provided by the starter fertilizer and struvite. On average, the rock phosphate provided an improvement in turfgrass quality when compared to the unfertilized control trials (Table 4). The grass species did not show any significant differences in quality in the first rating, but the creeping bentgrass trials were rated significantly higher in the second rating. This difference was most notable for the rock phosphate treatments. The soil type made no difference on quality.

The difference in quality between the rock phosphate and the control treatments indicates that some of the rock phosphate was available to the plants. It is interesting that in the second quality rating, creeping bentgrass was rated significantly higher than annual bluegrass in the rock phosphate treatments. This indicates that creeping bentgrass is either more tolerant of low-P conditions or was able to more effectively utilize the rock phosphate than annual bluegrass. Deficiency symptoms were apparent in the control and rock phosphate treatments for both grasses, although the symptoms were markedly different. The creeping bentgrass plants exhibited the typical phosphorus deficiency symptoms of thin purplish shoots, while the annual bluegrass species were obviously yellow at the base of the plant with no purple coloration present.

Table 4. Creeping bentgrass and Annual bluegrass quality ratings as affected by fertility treatment and root zone mineralogy.

Treatment	Rating 1	Rating 2	Avg. Rating
Starter Fertilizer			
Quartz sand			
Creeping bentgrass	3.83 b	4.83 a	4.33 a
Annual bluegrass	4.83 a	4.50 ab	4.66 a
Dolomitic sand			
Creeping bentgrass	3.66 bc	5.00 a	4.33 a
Annual bluegrass	4.16 ab	4.50 ab	4.33 a
Struvite			
Quartz sand			
Creeping bentgrass	3.66 bc	5.00 a	4.33 a
Annual bluegrass	3.00 cd	4.00 bc	3.50 b
Rock Phosphate			
Quartz sand			
Creeping bentgrass	2.50 d	3.66 cd	3.08 bc
Annual bluegrass	3.00 cd	2.00 fg	2.50 c
Dolomitic sand			
Creeping bentgrass	2.50 d	3.16 de	2.83 c
Annual bluegrass	1.66 ef	1.50 gh	1.58 de
Control			
Quartz sand			
Creeping bentgrass	1.16 f	1.66 gh	1.41 de
Annual bluegrass	1.16 f	1.00 h	1.08 e
Dolomitic sand			
Creeping bentgrass	2.50 d	2.50 ef	2.50 c
Annual bluegrass	2.33 de	1.33 gh	1.83 d

Bray Test

The results of the Bray P tests show significantly higher amounts of available phosphorus in the rock phosphate treatments compared to the starter and control treatments. The results also suggest that there was much more available phosphorus in the quartz sand compared to the dolomitic sand. There are obvious discrepancies between the Bray results and the trends suggested by dry matter yield and quality measurements. It would be logical for total phosphorus to be higher in the rock phosphate, but it was clearly not in a plant available form as the test is meant to measure otherwise the plants would have taken it up. The difference between the quartz sand and the dolomitic sand is further evidence of an overestimation. The same amount of phosphorus was added to both soil types and plant growth and quality do not suggest different uptake levels. Also as phosphorus is relatively immobile in the soil and leaching was kept to a minimum, leaching is not a likely pathway for loss. This discrepancy suggests that the Bray test is not suitable for use when phosphorus-bearing minerals like apatite are present in appreciable quantities in quartz sand. The numbers for the dolomitic sand correlated well with the observations of turf yield and visual quality.

Table 5. Available phosphorus determined by Bray method averaged over different treatments in different root zones

Root zone medium	Fertilizer treatment	Bray extractable P
Quartz sand		mg kg^{-1}
	Starter fertilizer	31.18
	Struvite	22.21
	Rock P	110.77
	Control	5.36
Dolomitic sand		
	Starter fertilizer	21.02
	Rock P	12.49
	Control	5.02

Root Mass

The starter fertilizer treatments had significantly greater root mass compared to the others (Table 6). The rock phosphate trials had slightly more rooting than the control pots but not to any statistical significance. The increased rooting in the starter fertilizer treatments is not as expected as it was with increased yield and quality. It has been suggested by K. Paré et al. (2006), that turfgrass is capable of building a denser root system in nutrient deficient systems in order to “mine” for nutrients. This ability was not observed in this experiment, likely due to the extent of the deficiency. In the extremely phosphorus deficient environment of the control and rock phosphate trials, it is likely that the plants never reached the critical threshold to be able to produce enough roots to mine for extra nutrients. Soil type appeared to be a surprisingly significant variable in root mass with much more recovered in the dolomitic sand (Fig. 1). It seemed unlikely that root zone mineralogy would have such a significant effect on root mass since there were no real differences in yield or quality, so we tested the loss on ignition of the soils. An average of 13% of the dolomitic soil weight was lost after four hours in the Muffle furnace while the loss in the quartz sand was negligible, which explains the discrepancy between the soil types. Since there was no organic matter present in the dolomitic subsoil, this loss on ignition is a result of the volatilization of carbonates. There were no differences in root mass observed between the grass types, which came as a surprise as it is believed that creeping bentgrass is capable of a deeper, more extensive root system. This physiological difference could have been inhibited by the shallow depth of the pots.

Table 6. Root mass of creeping bentgrass and annual bluegrass as affected by fertility and root zone mineralogy.

Treatment	Root mass
	$g\ pot^{-1}$
Starter Fertilizer	
Quartz sand	
Creeping bentgrass	0.64 cde
Annual bluegrass	0.80 bcd
Dolomitic sandy loam	
Creeping bentgrass	1.63 a
Annual bluegrass	1.12 b
Struvite	
Quartz sand	
Creeping bentgrass	0.44 cdef
Annual bluegrass	0.40 def
Rock Phosphate	
Quartz sand	
Creeping bentgrass	0.33 ef
Annual bluegrass	0.38 def
Dolomitic sandy loam	
Creeping bentgrass	0.65 cde
Annual bluegrass	0.83 bcd
Control	
Quartz sand	
Creeping bentgrass	0.10 f
Annual bluegrass	0.13 f
Dolomitic sandy loam	
Creeping bentgrass	0.65 cde
Annual bluegrass	0.87 bc

Tissue concentrations

The P concentrations found in tissue samples of the verdure qualify the response trends seen in the other measures. Starter fertilizer and struvite treatments had more than twice the P concentrations compared with the rock phosphate treatments, while the rock phosphate treatments contained twice as much tissue P than the control treatments. There was no consistent difference between the sand or grass varieties.

Table 7. Tissue P concentration of the verdure harvested on 4/27/07

Treatment	Tissue P
Starter Fertilizer	%
Quartz sand	
Creeping bentgrass	0.93 ab
Annual bluegrass	1.05 a
Dolomitic sand	
Creeping bentgrass	0.72 c
Annual bluegrass	0.83 bc
Struvite	
Quartz sand	
Creeping bentgrass	0.87 abc
Annual bluegrass	0.89 abc
Rock Phosphate	
Quartz sand	
Creeping bentgrass	0.43 def
Annual bluegrass	0.44 de
Dolomitic sand	
Creeping bentgrass	0.47 d
Annual bluegrass	0.47 d
Control	
Quartz sand	
Creeping bentgrass	0.21 g
Annual bluegrassannua	0.26 fg
Dolomitic sand	
Creeping bentgrass	0.28 efg
Annual bluegrass	0.22 g

Conclusions

Readily available sources of phosphorus, as used in the starter fertilizer and struvite treatments, increase dry matter yield, root mass, and quality of turfgrass plants grown from seed when compared to less available sources. Fine grade rock phosphate was taken up by the plants, but to a lesser extent than the ammoniated phosphorus delivered by starter fertilizer and struvite. The major differences observed between the dolomitic and quartz based root zones seemed to be a result of collection and testing procedures rather than actual nutrient mineralization or physiological effects on the plants. There were no consistent significant differences between grass types observed in this experiment, though it is possible that the small size of the pots and the relatively short length of the experiment trivialized any differences in physiological response to phosphorus availability.

References

Goss, R.L., S.E. Brauen, and S.P. Orton. (1975). The effects of N, P, K and S on Poa annua L. in bentgrass putting green turf. *Journal of the Sports Turf Research Institute*. *51*, 74-82.

Higgins, J. (2003). *Strategies for eradicating annual bluegrass.* Through the green, September/October.

Murphy, J., and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta 27:31-36.

Paré, K., M. Chantigny, K. Carey, W. Johnston, and J. Dionne, (2006). Nitrogen uptake and leaching under annual bluegrass ecotypes and bentgrass species: A lysimeter experiment. *Crop Science* 46, 2, 847-853.

Varco, J.J., and J.B. Sartain, 1986. Effects of phosphorus, sulfur, calcium hydroxide, and ph on growth of annual bluegrass. *Soil Science Society of America Journal*. 50, 128-132

Vargas Jr., J. M., & Turgeon, A. J. (2004). *Poa annua*. Hoboken, New Jersey: John Wiley & Sons, Inc.