Phosphorus availability in turfgrass rootzones after organic and synthetic N fertilizer apps

ORGANIC FERTILIZERS have increased in popularity over the past 10 years due to the belief they are more environmentally sound to use than synthetic fertilizers. Most fertilizers derived from organic materials contain phosphorus as well as nitrogen, so use may be affected in states that legislate the application of P to lawns. States are considering exempting organic fertilizers from their zero-P legislation, as Wisconsin did, because it is thought that P from organic sources is less likely to be lost in leachate or runoff.

Fertilizers are applied on turfgrasses as needed based on N form and content. Many organic fertilizers contain as much P as N in their formulations, and therefore similar amounts of P and N are applied with each application. Soil tests in native soil and a fairway sand and peat mix used in the Pacific Northwest showed that organic fertilizers applied at rates to provide adequate N for acceptable turf increased soil Bray-1 P levels from 16 to 18 mg/kg to 23 to 66 mg/kg within 3 years. Oxalate extractable Fe, Al, and P was determined for all treatments in both soils and used to calculate phosphorus saturation (PSI). PSI values from sand treated with one organic fertilizer source were significantly higher than measured in other treatments, indicating future risk of P loss with repeated applications of this organic fertilizer.

Because of concerns about phosphorus effects on eutrophication of surface waters, local and/or state governments New Jersey, Maine, Florida, Wisconsin, Minnesota, and Washington have adopted restrictions on residential use of phosphorus-containing fertilizers. Urban and suburban lawns pose a specific concern for potential P loss, because managed turfgrass often abuts impermeable surfaces such as sidewalks, driveways, and curbs, which provide a direct conduit for P transport to storm drains and surface water.

Increased recycling of organic waste streams into organic slow-release fertilizers has led to increased availability and popularity of these materials. Many homeowners and professional landscapers use these natural organic slow-release fertilizers to limit the loss of nutrients from lawns through leaching and runoff.

Some phosphorus-restriction legislation is considering exempting organic fertilizers based on the premise that risk of P loss is reduced with these materials. However, many natural organic-based fertilizers (particularly manures and municipal biosolids) supply an excess of P when applied at rates to meet plant N needs. When high-P organic fertilizers are applied repeatedly, excess P accumulates in soil, potentially increasing the risk of runoff and leaching loss.

The risk of loss of P from natural organic sources depends on the availability as well as the concentration of P in those sources. Although P from organic sources is generally less available to leaching and runoff than synthetic P sources, P availability varies widely by source. Biosolids P tends to be less available than manure P, but even among biosolids sources P availability can vary widely.

Understanding the effect of repeated applications of natural organic lawn fertilizers on soil test P can provide guidance for the suitability of these materials in P sensitive areas. If P availability is low enough in organic fertilizers, it could be possible to use them without increasing the risk of water quality degradation. Evidence shows that the risk of soluble P loss occurs at much higher soil test levels than those needed for agronomic sufficiency.

Researchers have proposed alternative soil tests to assess environmental risks, such as phosphorus saturation (PSI), dissolved P index, or water extractable P. No environmental soil P test is widely recognized and in common use.

Agronomic tests also have some value as environmental indicators. Another factor is the effectiveness of P fertilizers in changing

Table 1. Fertilizer products applied to soil and sand root zones at WSU-Puyallup, RL Goss Research Facility in Puyallup, WA, 2008-2011.

Fertilizer product	Rate	Fertilizer formula	Ingredients
Organic 6-7-0	1×	6-7-0[a]	Biosolids, 75% insoluble N
Organic 6-7-0	1.5×	6-7-0	Biosolids, 75% insoluble N
Organic 8-3-5	1×	8-3-5	Feather, meat, blood, fish, poultry and bone meals, 90% insoluble N
Organic 8-3-5	1.5×	8-3-5	Feather, meat, blood, fish, poultry and bone meals, 90% insoluble N
PCSCU 20-5-10	1×	20-5-10	Proforma, 60% of N as PCSCU, monoammonium phosphate, potassium sulfate

[a] Organic 6-7-0 was originally labeled as 5-4-0, but analysis form 2008-2010 showed that it consistently contained 6% N and >7% P_2O_5. The label was changed to 6-7-0 to reflect that analysis in 2010.

soil test P (17), with greater effectiveness indicating more rapid change in soil test P per unit of fertilizer P applied (poorer buffering), and greater long term risk of P loss. The objective of this study was to determine how repeated N-based applications of organic fertilizer sources to established turfgrass affected soil test P and P saturation in native soil and a sand-based rootzone mixture under field conditions.

▼ Table 2. Annual nitrogen (N) and phosphorous (P_2O_5) application rates for soil and sand root zones.

Fertilizer product	Soil	Sand	Soil	Sand
	kg N/ha/yr		kg P_2O_5/ha/yr	
Organic 8-3-5 1×	147	245	55	92
Organic 8-3-5 1.5×	221	368	83	138
Organic 6-7-0 1×	177	294	206	343
Organic 6-7-0 1.5×	265	441	309	515
PCSCU 20-5-10	147	245	37	61

FERTILIZER APPLICATIONS AND MEASUREMENTS

For this study, fertilizers were applied on an N basis, using natural organic and synthetic fertilizer sources on perennial ryegrass plots on two rootzone media over 3 years (July 2008-June 2011). Soil samples from the plots were analyzed to determine changes in P availability in each treatment area after three years of applications. Application rates of the fertilizers were based on their N content for the original experimental design; therefore, P levels were not equalized among treatments.

Perennial ryegrass was grown on both a Puyallup fine sandy loam native soil (coarse-loamy over sandy, isotic over mixed, mesic Fluventic Haploxerolls) and a USGA sand/peat 90/10% rootzone mixture in the Puyallup Valley of western Washington, south of Seattle. The plots on the native soil were maintained at 62.5 mm as a home lawn and the plots on the sand/peat mixture were maintained at 12.5 mm as a golf course fairway. All grass clippings were returned to the plots. The experimental design for each site was a randomized complete block with five fertilizer treatments and four replications. Plot size was 1.5 m by 3 m.

Each plot was fertilized with one of five treatments. The treatments included two natural organic fertilizer sources at a 1× and a 1.5 × N rate and a synthetic slow-release product at a 1× N rate. The target annual N rate (1×) for the native soil plots was 147 kg/ha , consistent with recommendations for home lawns, while the target annual N rate (1×) for the sand/peat plots was 245 kg/ha, consistent with golf course fairway management. Fertilization was split into three equal applications per year on the native soil plots and five applications per year on the sand/peat plots. The 1.5× rate treatments received 50% more fertilizer on each application date.

The organic fertilizer sources were Organic 6-7-0, made from anaerobically digested and heat-dried municipal biosolids, and a commercially available Organic 8-3-5, made from mixed animal by-products. In the field, the Organic 6-7-0 N application rate was slightly higher than the Organic 8-3-5 rate. This was because the product was originally labeled as 5% N (5-4-0), but subsequent analysis showed it to be 6-7-0. Based on the fertilizers applied to each treatment on an N basis, the amount of P added per year in the organic fertilizers ranged from 55 to 138 kg P O /ha for the Organic 8-3-5 and from 206 to 515 kg/ha for the Organic 6-7-0. The synthetic slow-release control N source was a 20-5-10 formulation containing polymer-coated, sulfur-coated urea (PCSCU). The P in this formulation was monoammonium phosphate. It was applied at the same N rate as Organic 8-3-5. Phosphorus rates for this material were 37 kg P O /ha/year for native soil managed as home lawn and 61 kg/ha/year for sand managed as a golf course fairway.

For the native soil plots managed as a home lawn, fertilizer application dates were August and October 2008; May, June, and Oct 2009; April, August, and October 2010; and April 2011. For the sand-based plots managed as a golf course fairway, fertilizer application dates were August, October, and November 2008; April, June, July, September, and November 2009; March, May, August, September, and November 2010; and March and May of 2011.

In July of 2011, six to eight 25-mm-diameter soil cores were removed to a 100-mm soil depth from each plot. Unfertilized control samples were taken at the same time from untreated areas surrounding the plots. Verdure and thatch were discarded. Samples were mixed, placed in paper bags, moved to a greenhouse, and allowed to air dry for 1 week. After drying the samples, they were analyzed for Bray 1-P and ammonium oxalate extractable Fe, Al, and P. This data was used to determine phosphorus saturation (PSI) in each treatment in each soil type. We also compared the effectiveness of the P fertilizers in changing Bray-1 P, calculated as the slope of the linear regression of Bray-1 P vs. total fertilizer P applied. All data were analyzed using SAS PROC ANOVA, with means separation by least significant difference following a significant F-test.

Phosphorus saturation was calculated as: PSI = P / [Fe + Al], where P, Fe, and Al are the molar concentrations of oxalate-extractable phosphorus, iron, and aluminum in the soil.

A similar oxalate extraction and calculation was done on the two natural organic fertilizers to determine the relative degree of P binding with Fe and Al in each material.

PHOSPHORUS LEVELS AND POTENTIAL LOSSES

Values for Bray-1 extractable P were significantly higher in most of the Organic 6-7-0 treatments when compared to the PCSCU fertilizer treatment. In the native fine sandy loam soil managed as home lawn, the plots receiving Organic 6-7-0 1.5× treatments were significantly higher in extractable P than the PCSCU treatment, and in the sand-based fairway soil, both sets of plots receiving Organic 6-7-0 treatments were significantly higher in extractable P than the PCSCU treatment.

The plots receiving Organic 8-3-5 treatments showed a trend for higher Bray 1-P than the plots receiving synthetic fertilizer, but differ-

▼ **Table 3.** Bray 1-P saturation (PSI_{ox}) in the soil root zone after three years of fertilizer application, 2008-2011.

Fertilizer product	Soil Bray 1-P	Soil test level[a]	PSI_{ox}[b]
	mg/kg		
PCSCU 20-5-10	19.3 B[c]	low	0.13
Organic 8-3-5 1×	22.8 B	medium	0.12
Organic 8-3-5 1.5×	21.3 B	medium	0.13
Organic 6-7-0 1×	35.0 A	medium	0.13
Organic 6-7-0 1.5×	38.5 A	medium	0.14
LSD	6.8	–	NS

[a] Low = < 20 mg/kg; medium = 20-40 mg/kg; high = 40-100 mg/kg; excessive = >100 mg/kg. Horneck et al. (7).
[b] Phosphorous saturation index = P_{ox}/ [Fe_{ox} + Al_{ox}]
[c] Means followed by the same letter are notsignificantly different. P = 0.05. Mean of four samples. Control Soil Samples (untreated areas surrounding plots) Bray-1P Test = 18mg/kg.

▼ **Table 4.** Bray 1-P and P saturation (PSI_{ox}) in the sand root zone after three years of fertilizer application, 2008-2011.

Fertilizer product	Sand Bray 1-P	Soil Test Level	PSI_{ox}[a]
	mg/kg		
PCSCU 20-5-10	23.5 B[b]	medium	0.09 C
Organic 8-3-5 1×	27.3 B	medium	0.10 C
Organic 8-3-5 1.5×	28.0 B	medium	0.11 BC
Organic 6-7-0 1×	66.3 A	high	0.12 AB
Organic 6-7-0 1.5×	75.3 A	high	0.13 A
LSD	12.8	–	0.02

[a] Phosphorous saturation index = P_{ox}/ [Fe_{ox} + Al_{ox}]
[b] Means followed by the same letter are not significantly different. P = 0.05. Mean of four samples. Control Soil Samples (untreated areas surrounding plots) Bray-1P Test = 16mg/kg.

ences were not significantly different in either soil. Bray-1 test levels were in the low range in the pre-fertilization control soils and the PCSCU treatment in native soil, but were in the medium or high ranges following 3 years of application of natural organic fertilizers. In the Pacific Northwest, turfgrass shows little or no response to added P in soils that test in the medium or high range (> 20 mg P/kg soil).

To determine if the potential risk of soluble P loss had increased, oxalate extractions of Al, Fe, and P were run to determine if the fertilizer applications had affected P saturation (PSI) for each treatment and soil type. The results of these calculations showed no significant difference between PSI values for any of the fertilizer treatments on native soil after 3 years of fertilizer applications. However, on sand, both Organic 6-7-0 treatments had significantly higher PSI values than the other fertilizer treatments.

The change in Bray-1 P was much greater than the change in PSI, reflecting that the soils had exceeded the upper threshold for plant response to P, but had not yet reached a level of concern for soluble P loss. The PSI of the fertilizers alone was 16.6 for the Organic 8-3-5 compared with 3.8 for the Organic 6-7-0 biosolids product. The PSI of Organic 8-3-5 is similar to that of chicken manure (PSI = 15) as reported by Elliot et al., while the PSI for Organic 6-7-0 was higher than reported for a range of biosolids products (PSI = 0.47 to 1.4). The Organic 6-7-0 applications had a greater influence on Bray-1 P and soil PSI than the Organic 8-3-5, despite having a greater P binding capacity, because nearly four times as much P was applied in the Organic 6-7-0 than in Organic 8-3-5. Organic 6-7-0 applications added six to nine times as much P each year as the synthetic control, resulting in a large excess of applied P when products were applied to meet N needs.

We also calculated the relationship between the change in Bray-1 P applied for both natural organic fertilizers in both soils to compare the effectiveness of the fertilizers in raising soil test P. The change in Bray-1 P averaged 0.057 mg/kg for every kg/ha fertilizer P applied in the native soil, with no significant differences between the 8-3-5 and 6-7-0 fertilizers. In the sand/peat root zone mix the P effectiveness averaged 0.105 mg/kg Bray-1 P for every kg/ha fertilizer P applied, also with no differences between fertilizer sources. This suggests that the organic fertilizers had similar effects on soil test P per unit P applied, despite differences in the PSI of the two materials. Soil appeared to have a greater influence on P effectiveness than fertilizer, with the sand mix having a greater P effectiveness (less buffering) than the native soil. This is consistent with conclusions reached by Sneller and Laboski in agricultural soils fertilized with different types of manure. Because each experiment had only one synthetic P treatment, we could not calculate the P effectiveness of the synthetic P fertilizer in our soils.

The sand/peat experiment can be considered a worst case for soil response to P application, because the coarse-textured soil is poorly buffered and P application rates were higher than those used for home lawns. When organic fertilizer with high P concentration and high PSI was applied to the sand/peat plots, significant increases in both Bray-1 P and soil PSI were observed after 3 years. Although it would take longer, similar changes would occur in the native soil, eventually increasing the risk of leaching and runoff loss of P.

These results show the importance of evaluating fertilizer sources for the amount and availability of P. The soil test results show that Bray-1 P was higher when using P-rich organic fertilizer, compared with synthetic fertilizer containing P, because of the greater P application rate from the organic fertilizer when applied at rates to meet N needs. The greatest increase in Bray-1 P occurred in the sand-based fairway treatment. Changes in soil PSI were smaller, indicating only small changes in P saturation and the risk of P loss from the soil over the 3-year duration of this study.

Some organic fertilizers could have sufficiently low P concentrations and PSI values that they could be used for years without risk of increasing P loss from soil, but that did not appear to be the case for the fertilizers used in this study. Our results suggest that use of high-P organic fertilizers to meet turf N needs would not likely lead to increased risk of P loss in the short run, but repeated use in the long run could increase future P loss risk. This information can provide guidance for legislation regarding turf fertilizer sources, fertilization practices, and water quality. ■

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