MANURE PHOSPHORUS SOURCE AND RATE EFFECTS ON SOIL TEST LEVELS AND CORN GROWTH

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Introduction

Nutrient management planning has become an important tool in an effort to improve water quality. In Wisconsin, nutrient management regulations are in the process of moving to a phosphorus (P) based standard. As such, P budgeting and the P index will greatly influence manure applications. Thus, there is a need to better understand how soil test P changes with respect to P based manure application.

In Wisconsin, only 60% of the total P applied in manure is considered to be available to the crop during the first year after application (i.e. relative availability (RA) of 0.6). From a P budgeting standpoint, this means manure is 60% as effective at increasing soil test P as the same amount of total P applied as fertilizer.

Past research has shown that these assumptions are not always true. Studies have shown that manure phosphorus can vary from being more available to less available depending on animal species, manure type, and storage of the manure. Eghball et al. (2002) found that first year P availability of cattle feed lot manure was 85% in a field experiment. In a complimentary incubation study, beef cattle feedlot manure averaged 72% P availability compared to fertilizer while swine slurry averaged 66% P availability (Eghball et al., 2005). In an incubation study by Kashem et al. (2004), P amendments increased labile P levels to varying degrees with fertilizer increasing labile P the most followed by hog manure, cattle manure, and biosolids. In an incubation study Laboski and Lamb (2003) found that swine slurry applied at high rates increased soil test P more than fertilizer.

Most of the past research on manure P availability has been conducted in laboratory incubations. The purpose of this study was to determine manure P availability to corn on a total P applied basis, as compared to fertilizer in a field setting.

Materials and Methods

This study was conducted at the University of Wisconsin Agricultural Research Stations in Marshfield (central Wisconsin) and Arlington (south central Wisconsin). General characteristics for soil are provided in Table 1. The experimental design at these locations was a randomized complete block. Treatments consisted of five P sources at Arlington (fertilizer (0-46-0), dairy slurry, solid dairy manure, swine slurry, and poultry pellets) and four P sources at Marshfield (fertilizer, dairy slurry, solid dairy manure, and swine slurry) as well as a no P control for both locations. Table 2 contains characteristics of the manures used at both locations. Plot size was 10 by 30 feet.

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Table 1. Soil characteristics.

Location	Soil series	Taxonomic name	pH	P	K	Ca	Mg	OM
				ppm				%
Arlington	Plano silt loam	Fine-silty, mixed, superactive, mesic Typic Argiudolls	6.5	16.8	77.3	1784	535	3.7
Marshfield	Withee silt loam	Fine-loamy, mixed, superactive, frigid Aquic Glossudalfs	7.1	14.3	125.3	1441	433	2.7

Table 2. Manure characteristics.

Manure	Total N	NH_4-N	P	K	S	DM†
						%
Arlington						
Dairy slurry (lb/1000 gal)	34.25	14.89	5.27	20.10	1.64	10.3
Swine slurry (lb/1000 gal)	22.87	17.58	5.02	11.37	1.08	2.7
Dairy solid (lb/ton)	10.76	3.87	1.63	6.17	0.59	18.9
Poultry pellets (lb/ton)	70.55	8.82	33.9	42.53	3.85	84.0
Marshfield						
Dairy slurry (lb/1000 gal)	20.18	10.19	3.88	15.76	1.34	6.1
Swine slurry (lb/1000 gal)	25.2	17.56	4.72	10.37	1.02	2.8
Solid dairy manure (lb/ton)	9.46	2.68	1.67	10.44	2.68	19.9

†DM, dry matter.

Each P source was hand applied preplant at three target application rates of 80, 160, and 240 lb P_2O_5/a, or low, medium, and high rates. Total P in the manure was confirmed in the lab and actual P_2O_5 application rates calculated (Table 3). Manure credits for nitrogen (N), potassium (K), and sulfur (S), were taken and fertilizer was applied to all plots to meet total application rates of 200 lb N/a, 120 lb K_2O/a, and 15 lb S/a. Two days after treatment application, plots were chisel plowed to 8 in and the seed bed was prepared with a soil finisher. An adapted corn (*Zea mays)* hybrid was planted at each location.

Table 3. Amount of P applied for each P source and rate at Arlington and Marshfield.

Source	Phosphorus application rate: Low	Medium	High
		lb P_2O_5/a	
Arlington			
Fertilizer	83	166	248
Dairy slurry	76	152	227
Dairy solid	67	134	201
Swine slurry	62	125	187
Poultry pellets	77	154	230
Marshfield			
Fertilizer	83	166	248
Dairy slurry	57	114	171
Dairy	47	137	205
Swine slurry	59	117	176

Soil samples (0 to 6 inches) were taken in every plot prior to treatment application, 2, 4, and 10 weeks after application, and post harvest. Samples were dried and ground to pass a 2 mm sieve. Phosphorus was extracted with Bray-1 and analyzed colorimetrically (Frank et al., 1998).

Plant samples were taken throughout the growing season. Whole plant samples were taken at the V5 growth stage, ear leaf samples were taken at tasseling, and whole plant samples for silage yield were taken at physiological maturity. All plant samples were dried and ground to pass a 2 mm sieve and then digested (H_2SO_4 + H_2O_2) and analyzed colorimetrically for total P.

For each location, linear regression was used to model the relationship between the change in STP with P application for each P source and date of sampling. The slope of the regression line for each manure source on a given date and location was compared to the slope of the regression line for fertilizer on the same date and location. If the slopes were significantly different, then manure changed soil test P differently than fertilizer and the relative availability (RA) was calculated. Relative availability was calculated as the ratio of the slope of the regression line for manure to the slope of the regression line for fertilizer. Silage harvest P uptake for Arlington and Marshfield and silage yield at Marshfield were fit with a linear plateau model.

Results and Discussion

In general, as total P applied increased so did soil test P (STP) levels. However, different trends were evident between locations and sampling dates (Figure 1, Table 4). At Marshfield, fertilizer and swine slurry showed an immediate and similar increase in STP at the 2-week sampling date (Figure 1). Dairy slurry and solid dairy manure changed STP similarly and significantly less than fertilizer and swine slurry. At the post harvest sampling, all sources changed STP similarly with the change being less than at 2 weeks. At Arlington, fertilizer increased STP significantly more than all manures. By post harvest sampling, all sources changed STP similar to fertilizer and were not significantly different. At Arlington changes in STP at post harvest were less than at 2 weeks after application. The reduction in STP change at post harvest for both locations could be a result of P binding with soil over time or possibly from crop removal.

Table 4. Comparison of the ability of manure P to change STP similarly to fertilizer P.

	Arlington		Marshfield	
Source	Two week	Post harvest	Two week	Post harvest
	P value †			
Dairy slurry	0.0001	0.3127	0.0028	0.3687
Dairy solid	<0.0001	0.4405	0.0626	0.4728
Swine slurry	<0.0001	0.2935	0.7114	0.3106
Poultry pellets	<0.0001	0.6210	—	—

† H_o: slope of change in STP with manure P applied = slope of change in STP with fertilizer P applied.

Relative availabilities were calculated for the manure sources at the 2 week sampling date (Table 5). Manure sources behaved differently depending on location. At Marshfield, swine slurry was the only source that was as immediately available as fertilizer. The RA of dairy slurry was similar at Marshfield and Arlington, 0.22 and 0.19 respectively. Solid dairy manure had a

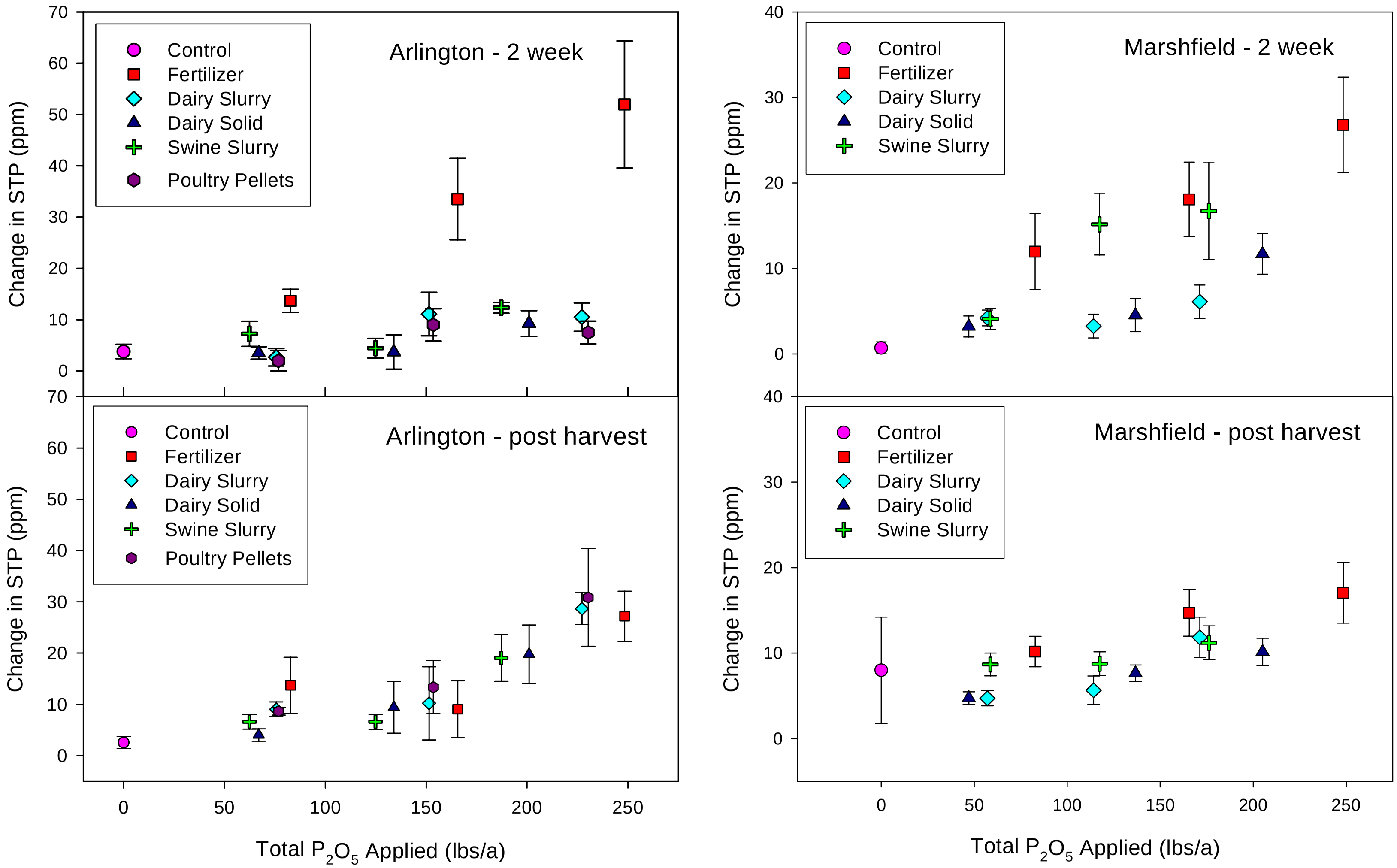

Figure 1. Change in STP with P_2O_5 applied for each P source at Arlington and Marshfield at the 2-week and post-harvest sampling date.

RA of 0.58 at Marshfield which was greater than 0.19 at Arlington. The range of RA's from the different manures was small at Arlington (0.16 to 0.22), whereas, at Marshfield the range was large (0.19 to 1.2) (Table 5). For the post harvest sampling, there was no significant difference between fertilizer and manure sources within a location, thus the RA for all manure sources was 1.00. The post-harvest results suggest that the current RA of 0.6 for manure the first year after application may be underestimating P availability to the crop, based on changes in STP, and may not be taking into consideration manure or soil type differences.

Table 5. Relative availability of manure sources at 2-week sampling date. †

	Relative availability	
Source	Arlington	Marshfield
Dairy slurry	0.22 ***	0.19 **
Dairy solid	0.19 ***	0.58 *
Swine slurry	0.16 ***	1.20 NS
Poultry pellets	0.18 ***	—

NS = not statistically significant
*Significant at the 0.1 probability level
**Significant at the 0.05 probability level
***Significant at the 0.001 probability level
† If relative availability (RA) = 1, then manure P is as available as fertilizer. If RA< 1 and is significant, then manure P is less available than fertilizer. If RA> 1 and is significant then manure P is more available than fertilizer.

At Marshfield a linear plateau model showed that P uptake increased as total P applied increased up to 123 lb P_2O_5/a for all sources and then plateaued (Figure 2). The high rate of solid dairy manure was removed from the data set before the model was fit because the large increase in uptake was caused by a large biomass yield. Greater biomass yield in the high rate of solid dairy manure is believed to result from a mulching effect of the solids (bedding, undigested feed, etc.) in the manure maintaining soil moisture. This was evidenced by the fact that the corn was slower to show signs of moisture stress during a period of dry weather. The relationship between total P_2O_5 applied and P uptake indicates that for corn, manure P is equally effective at supplying P as fertilizer. At Arlington, for all manure sources, P uptake increased as total P applied increased up to 168 lb P_2O_5/a. After this rate, P uptake leveled off. Fertilizer was not used in the linear plateau model because it appeared to follow a more linear trend and seemed to have reduced P uptake compared to manures; this relationship is being investigated further.

At Marshfield, silage yield response to applied P was fit to a linear plateau model (Figure 3). Again, data from the high rate of solid dairy manure were not used for the reason explained previously. Silage yield increased as total P applied increased up to 91 lb P_2O_5/a and then plateaued. Trends in silage yield were not as easily observed in the Arlington data (data not shown). At Arlington, it is believed that the variation in initial soil test levels within the field may have affected the P responsiveness. Additional statistical analysis is being conducted on this data.

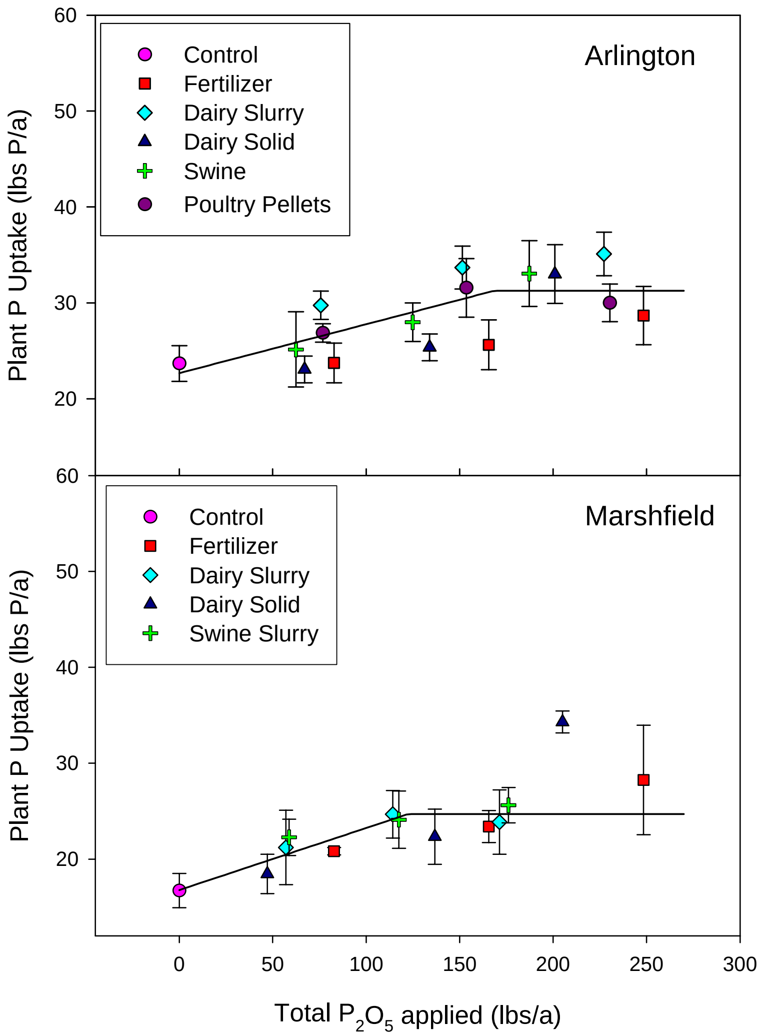

Figure 2. Relationship between plant uptake of phosphorus in silage and P_2O_5 applied for each P source at Arlington and Marshfield.

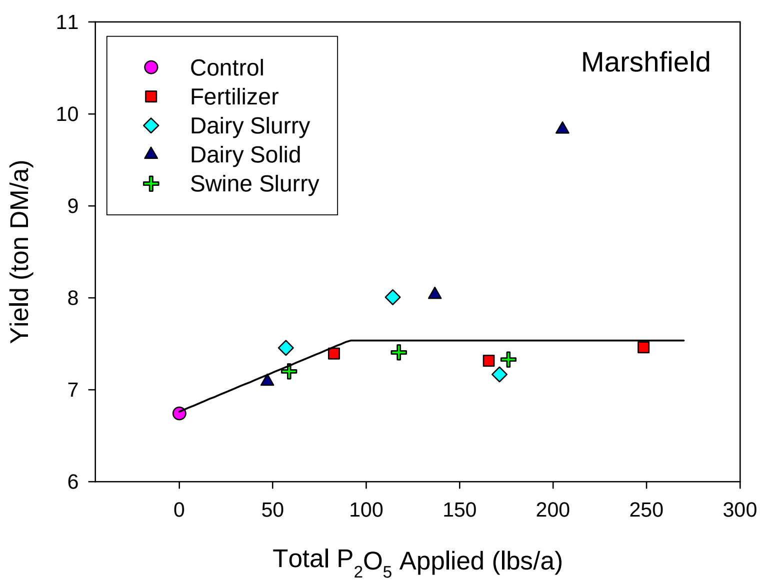

Figure 3. Relationship between silage yield and P_2O_5 applied for each source at Marshfield.

Conclusions

Differences between P sources in their ability to change STP were observed. Additionally, change in STP varied with soil and manure type. This implies that using a constant availability coefficient, such as 60% of total P applied, for all manures may not be the most effective way to account for manure P. Details of these relationships will be investigated further. From the P uptake and yield data, manures are equivalent sources of P for corn based on total P applied. Thus, manure P availability in terms of crop need appears to be 100%. Phosphorus availability in relation to how it changes STP may not be as important to determining crop response and growth but rather play an important role in addressing environmental concerns from P loss. Through further analysis and research, a better understanding of the differences between manure sources and soil types is hoped to be gained.

Acknowledgments

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