Trends in Soil Test Phosphorus and Sorption Capacity following Long-term Application of Poultry Litter and Commercial Fertilizers

Interim Report
MGPUB Project #2017324

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Project Purpose and Objectives: The purpose of this project is to understand the behavior of phosphorus in soils receiving long-term applications of manure or inorganic P fertilizers. This will allow us to better predict the overall risk of P loss due to legacy soil P and better predict how soil P chemistry changes over time as we build soil test P. The specific objectives of this proposal were to 1) maintain long-term P build-up plots located at Georgetown, DE and Chestertown, MD through the 2017 season, and 2) to examine deeper soil samples to determine the potential for P leaching in soils with a long-term history of P application.

Results and Discussion

Maintenance of University of Delaware Long-term P Buildup Sites

Long-term (18 year) field sites at Georgetown, DE and Chestertown, MD were maintained through 2017. Crop rotation at each site was continuous corn from 2000-2005 and corn/soybean rotation from 2005-2013. In 2014, we again planted corn and increased manure application rates to better simulate historical P buildup at the site. The full management history of the field sites (lime applications, N and K fertilization, total P applied, etc.) is available upon request. Historically, manure and fertilizer treatments were applied (to corn only) in 15 ft × 40 ft plots at each site based on the following treatments (six replications per treatment arranged in a randomized complete block design):

1. No P applied (control).
2. Poultry litter applied annually at 3 tons/A in 2000-2002. No litter applied in 2003-2016.
3. Poultry litter applied annually at 3 tons/A in 2000-2002; poultry litter applied at 1 ton/A in 2005, 2007, 2009, 2011, and 2013; 2 ton/A poultry litter in 2014 and 2016.
4. Poultry litter applied annually at 3 tons/A in 2000-2002; poultry litter applied at 2 tons/A in 2005, 2007, 2009, 2011, and 2013; 4 ton/A poultry litter in 2014 and 2016.
5. Poultry litter applied annually at 3 tons/A in 2000-2002; poultry litter applied at 3 tons/A in 2005, 2007, 2009, 2011, and 2013; 6 tons/A poultry litter in 2014 and 2016.
6. Poultry litter applied annually at 3 tons/A in 2000-2002; poultry litter applied at 4 tons/A in 2005, 2007, 2009, 2011, and 2013; 8 tons/A poultry litter in 2014 and 2016.
7. Fertilizer P (0-46-0) applied at 20 lb P_2O_5/A in 2000-2002; fertilizer P (0-44-0) applied at 20 lb P_2O_5/A in 2005, 2007, 2009, 2011, 2013, 2014, and 2016.

8. Fertilizer P (0-46-0) applied at 40 lb P_2O_5/A in 2000-2002; fertilizer P (0-44-0) applied at 40 lb P_2O_5/A in 2005, 2007, 2009, 2011, 2013, 2014, and 2016.
9. Fertilizer P (0-46-0) applied at 60 lb P_2O_5/A in 2000-2002; fertilizer P (0-44-0) applied at 60 lb P_2O_5/A in 2005, 2007, 2009, 2011, 2013, 2014, and 2016.
10. Fertilizer P (0-46-0) applied at 155 lb P_2O_5/A in 2000-2002; fertilizer P (0-44-0) applied at 120 lb P_2O_5/A in 2005, 2007, 2009, 2011, 2013, 2014, and 2016.

In 2017, the sites were planted in soybean and no manure or fertilizer P was applied. We had originally proposed moving to a corn, corn, soybean rotation, but opted to put the site back into soybean in 2017 due to declines in yield that were thought to be driven, in part, by multiple years of corn at one of the sites. Soybean grain samples and yield data were collected at harvest in late 2017. Plant tissue samples were dried and ground and submitted to the University of Delaware Soil Testing Laboratory for total elemental analysis by microwave digestion and inductively coupled plasma – optical emission spectroscopy (ICP-OES); results are pending. Routine soil samples were collected following harvest in late 2017 and submitted to the University of Delaware Soil Testing Laboratory for routine soil analysis. We also present the 2016 corn grain nutrient analysis in this report, as that data were not available at the time of report preparation last year.

Corn and Soybean Yields

The average corn grain yield at Chesapeake Farms (Chestertown) in 2016 was 151 bu/A and there were no P treatment effects on yield despite clear significant differences in soil test P concentrations. We saw a similar trend with soybean yields at Chestertown in 2017, with no P treatment effects on yield (data not shown). The average soybean yield was 53 bu/A.

Corn yields at Georgetown in 2016 ranged from 180 to 215 bu/A and plots receiving manure at rates of 2 tons/A or higher had significantly higher yields than plots receiving no P. However, yields in plots receiving manure or inorganic P faired equally well for the most part. In 2017, soybean yields were also affected by P treatment (Figure 1). In general, plots with a manure history out yielded the “No P” treatments and plots receiving the 4 and 6 ton/A poultry litter rate out yielded the plots receiving 20 or 60 lb/A P_2O_5.

Soybean grain samples were collected prior to harvest. All samples were dried and ground and submitted to the University of Delaware Soil Testing Laboratory; results are pending and will be reported in the 2017 report.

Soil Analysis

Results of routine soil analysis following harvest in 2015 and 2016 are shown for each site in Figure 2. As reported in previous years, we continue to see a clear effect of increased P application rate on soil test P concentrations in the silt loam soil at Chestertown and the loamy sand soil at Georgetown (Figure 2).

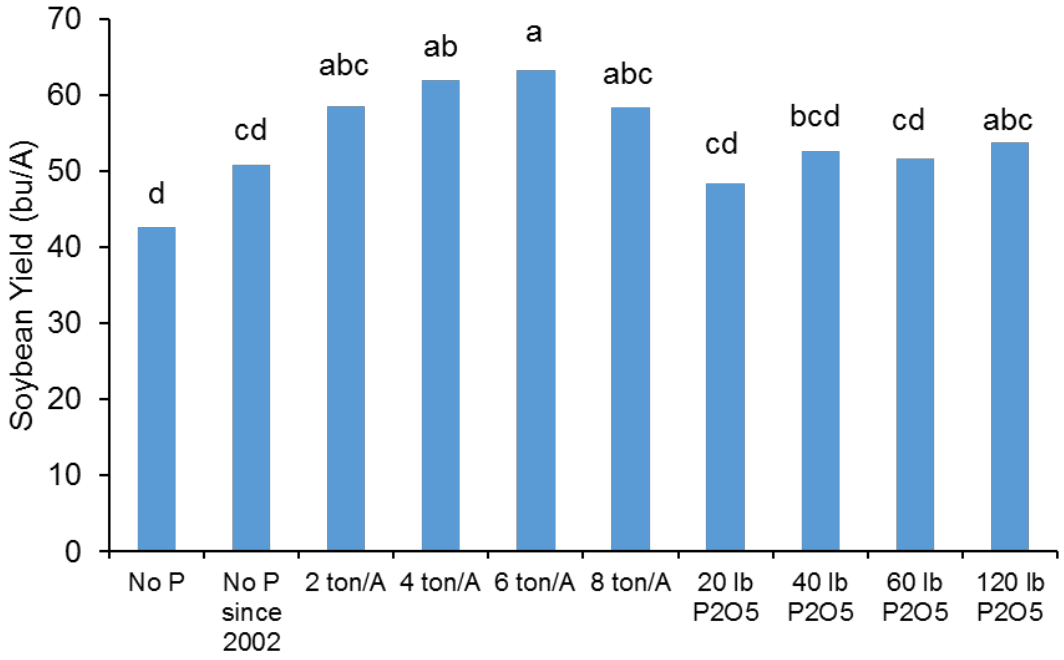

Figure 1. Effect of manure and fertilizer treatments on 2017 soybean grain yield at the Georgetown long-term P application sites. Bars with the same letter at the same site were not significantly different using Tukey's honestly significant difference test at P<0.05.

Previously, we had reported that there was no significant increase in soil test P concentrations at either site between 2013 and 2014 (data not shown), despite increased manure application rates in 2014. We are now seeing the effects of increased manure application rates on soil test P concentrations (Figure 2). Soils receiving the 6 and 8 ton/A poultry litter applications in 2014 and 2016 now exceed the 150 mg/kg Mehlich 3 threshold that triggers P risk assessment in MD and DE.

We were able to predict the rate of Mehlich 3 P change following increased manure applications rates (Figure 3). At the Chestertown site (Mattapex silt loam soil), application of 8 ton/A poultry litter in 2014 and 2016 increased soil test P at a faster rate than with the other poultry litter rates. With the loamy sand soil at Georgetown (Pepperbox soil), all manure applications resulted significant different rates of soil test P change than the no litter treatment. Regardless of sites, we showed flat or decreasing soil test P concentrations at both sites for all P treatments except the high commercial P and higher manure treatments (data not shown in this report). Phosphorus surplus resulted in the increase in soil test P over time. Most application rates of P to corn resulted in P balance or P deficit over the study period. We plan to share this information with MGPUB producers in more detail as we complete the data analysis.

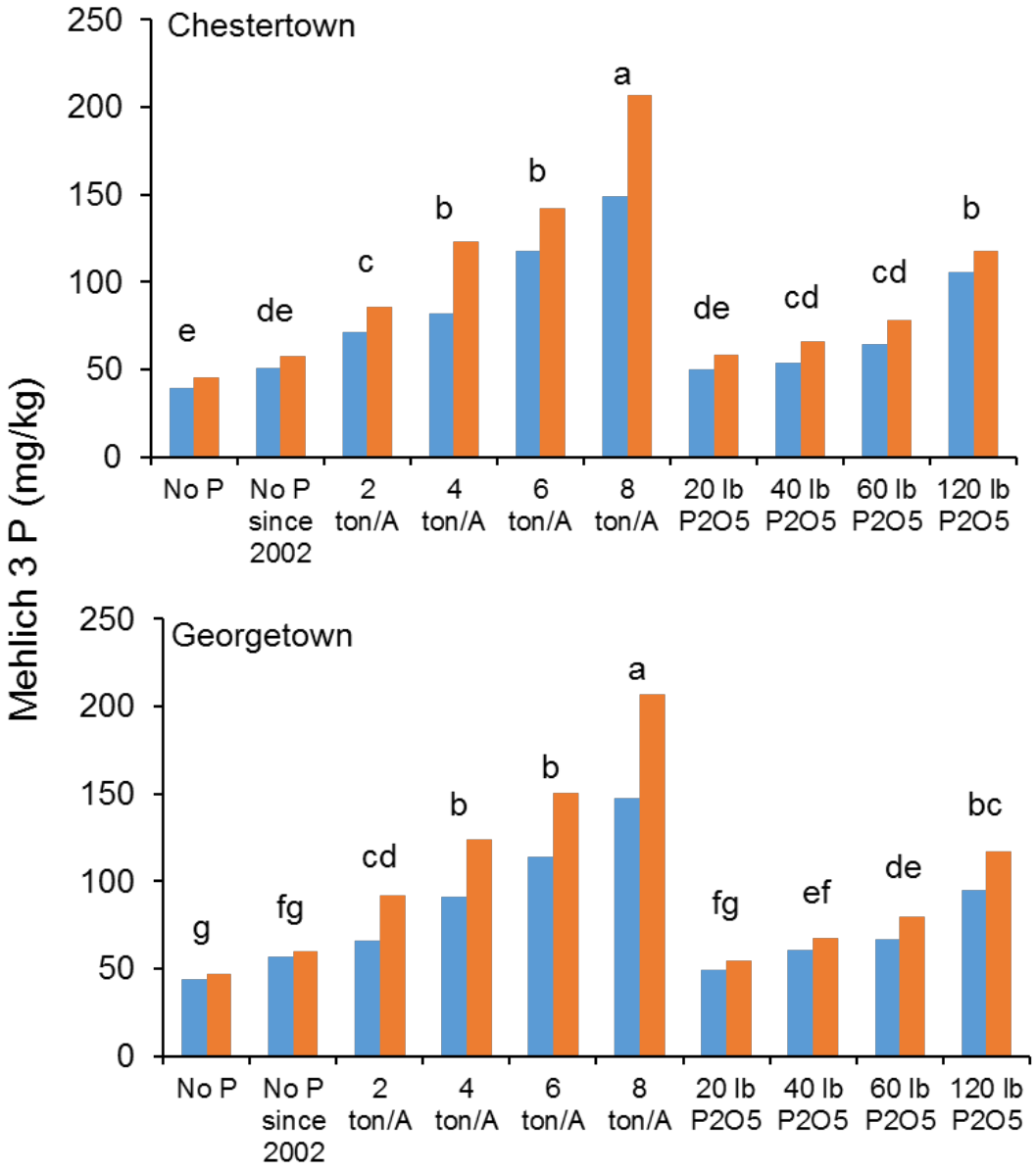

Figure 2. Effect of manure and fertilizer treatments on 2015 (blue/left bars) and 2016 (orange/right bars) post-harvest soil test P at the Chestertown and Georgetown long-term P application sites. Bars with the same letter were not significantly in 2016 different using Tukey's honestly significant difference test at P<0.05. Statistics for 2015 samples were reported in the 2016 report.

We are seeing a trend for increases in soil test P with manure application at all rates (positive exponent); however, year to year variability in soil testing may be influencing the estimated trend for the 2 and 4 ton/A litter rate, since application of P over the rotation tended to be near or less than crop P removal (see Rotational P Balance section below). We are also working to complete this type of analysis for the entire study period (2000-2017 for commercial fertilizer treatments and 2004-2013 for poultry litter applications). Preliminary results from our longer-term analysis

suggest that reductions of soil test P was possible when applications of poultry litter and commercial P fertilizer when total rotational P application rates were below crop removal rates.

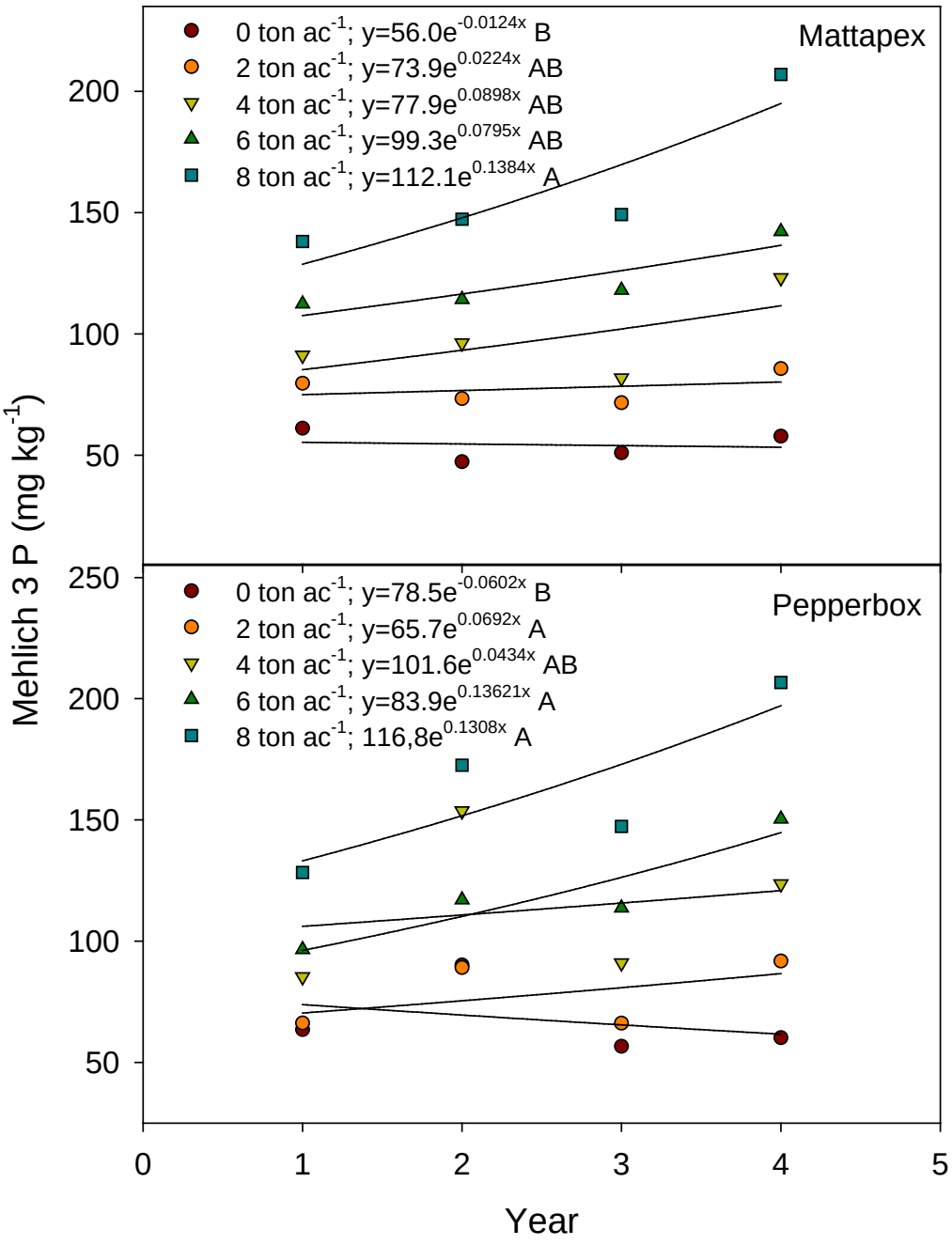

Figure 3. Trends in soil test P following application of poultry litter to soils at the Chestertown (Mattapex) and Georgetown (Pepperbox) sites at 0, 2, 4, 6, and 8 tons/A.

Routine soil samples were collected immediately following harvest in 2017. All samples were dried and ground and submitted to the University of Delaware Soil Testing Laboratory; results are pending and will be reported in the 2017 report.

We also collected deep soil samples from three replications of the No P, high manure, and high triple superphosphate treatments at the Georgetown site in 2016. Samples were analyzed for routine soil analysis to determine if P (and other nutrients) were leaching below the root zone. Samples were collected at three depth increments: 0-12, 12-24, and 24-36 inches. Note that nutrient content of the 0-12 inch samples is lower than our traditional routine sample analysis because those samples were collected to a depth of 8 inches. We saw no evidence of P leaching in our deep samples, even in plots receiving the 8 ton/A poultry litter rate; we did see the K concentrations were higher with the manure application and that there was evidence of enrichment of K in the deep samples (Figure 4). We recommend deep sampling in a few more years of high litter rates to confirm that P is still not leaching.

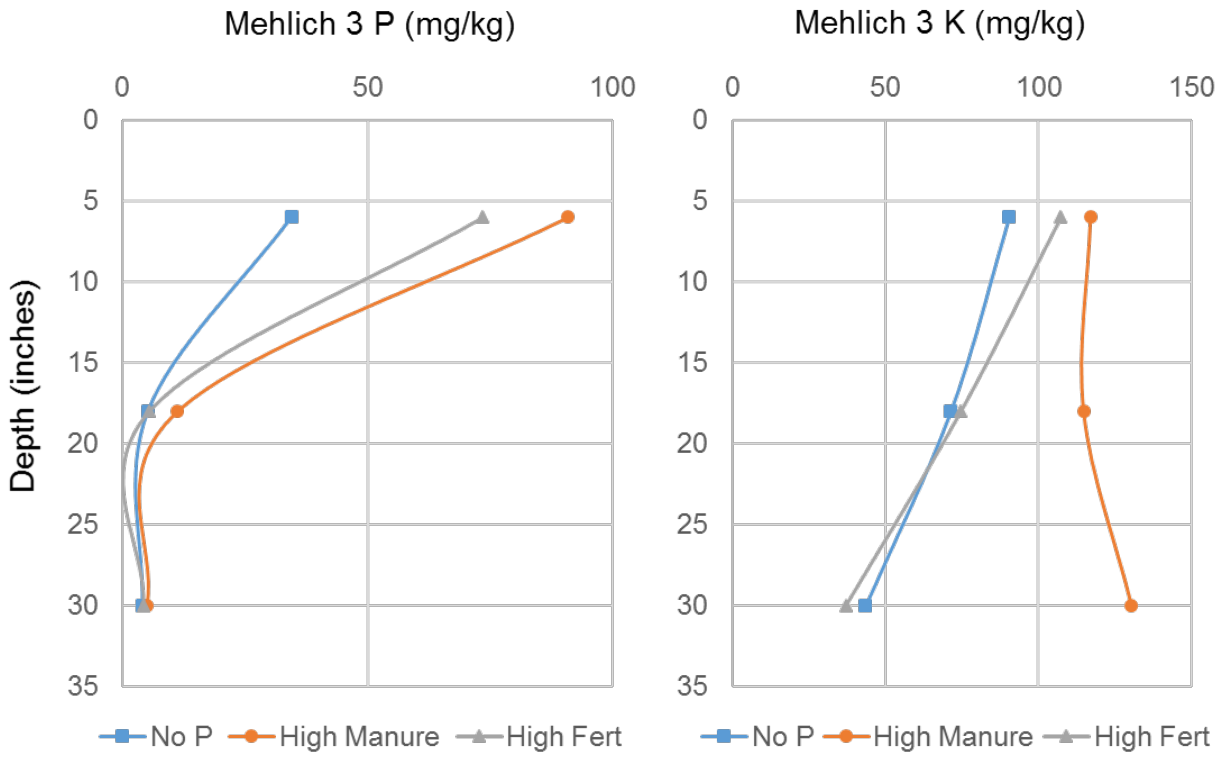

Figure 4. Concentrations of soil test P (left) and K (right) in soil samples collected from the Georgetown plots. Samples were collected at 0-12, 12-24, and 24-36 inch depths.

Rotational Phosphorus Budgets

In 2014 and 2016, P fertilizer and poultry litter treatments were applied in advance of corn planting. Poultry litter application rates in 2014 and 2016 were more indicative of historical manure applications rates, which resulted in wide-spread build-up of soil test P within the region. The rotational P budget is presented in Table 1 for the two year corn/full season soybean rotation. When P budget values are negative, that indicates that more P was removed from the site then

applied as poultry litter or triple super phosphate (nutrient deficit). At both sites, the plots receiving 4 ton/A litter or 120 lb/A P_2O_5 was near nutrient balance, while the higher manure rates provided more P than removed by crops. All other treatments resulted in a nutrient deficit.

The 2016-2017 rotational P budget is pending 2017 soybean grain analysis and, therefore, is not presented in this report. Total P application rates in 2016 are presented in Table 2. Note that total P application rates with the manure were higher in 2016 than 2014 due to poultry litter characteristics. Corn yields in 2016 were better at Chestertown than in 2014, but worse in Georgetown. Soybean yields were comparable in both years. These factors will ultimately affect the rotational P budget at both sites.

Table 1. Total rotational P budget for 2014 and 2015 at the University of Delaware long-term P application sites in Georgetown and Chestertown.

Manure or Fertilizer Application Rate	**Total P Applied**	**Total P Removed**	**P Budget**
	lb/A		
Georgetown, DE			
No P	0.00	41.13	-41.13
No P (with manure history	0.00	44.94	-44.94
2 tons/A	29.9	58.29	-28.36
4 tons/A	65.5	63.12	2.36
6 tons/A	94.9	66.29	28.63
8 tons/A	113	65.18	47.72
20 lb P_2O_5/A	9.78	48.03	-38.25
40 lb P_2O_5/A	19.6	55.16	-35.60
60 lb P_2O_5/A	29.4	56.81	-27.46
120 lb P_2O_5/A	58.7	60.88	-2.19
Chestertown, MD			
No P	0	49.53	-49.5
No P (with manure history	0	53.40	-53.4
2 tons/A	28.6	66.35	-37.7
4 tons/A	59.6	64.57	-4.97
6 tons/A	93.4	65.75	27.6
8 tons/A	118	69.50	48.2
20 lb P_2O_5/A	8.73	55.33	-46.6
40 lb P_2O_5/A	17.5	55.93	-38.5
60 lb P_2O_5/A	26.2	56.90	-30.7
120 lb P_2O_5/A	52.4	59.51	-7.15

Table 2. Total P application rate applied in poultry litter prior to planting corn in 2016 at the University of Delaware long-term P application sites in Georgetown and Chesapeake Farms.

Manure Application Rate (tons/A)	Total Phosphorus Applied (lb/A)	
	Georgetown	Chesapeake Farms
2	44	46
4	88	92
6	132	138
8	176	184

Conclusions

Overall, our results continue to show how long-term application of manures and fertilizers affect the solubility of P in soils. We are currently working on holistic data analysis for the whole project period to improve our understanding of P behavior in soils. Preliminary results are showing that applications of poultry litter or commercial fertilizers at rates that are at or below crop removal will result in an overall decline in soil test P, even if these P sources are applied to "high" P soils. We also continue to show that yields at the Georgetown plots with manure history will yield more than the plots with no manure history, even when soil test P is in the agronomic optimum range. We are excited to share results from the project with MGPUB members in the future.

Detailed Expenditures

Expense	Total
Gasoline for travel to sites*	$143.46
Supplies (including fertilizer, seed, and field consumables)*	$45.82
Soil testing and plant analysis*	$4,100
Total	$4,289.28

*Gasoline charges are still pending. We were able to leverage existing supplies and other funds to reduce the supply costs during the 2017 season. MGPUB will not be invoiced for the supply and gasoline funds that were not spent during this period.

Occasions where MGPUB has received recognition

Data from this project were shared at scientific meetings including the Maryland Commodity Classic; MGPUB received recognition for funding at all events. We will continue to recognize MGPUB as we prepare publications and present data to clientele.