iStock/SimplyCreativePhotography

Long-Term Impacts of Poultry Litter on Soil pH and Phosphorus in No-Till

By Catherine Fleming-Wimer, Mark Reiter, Rory Maguire, and Steve Phillips

Continuous no-till corn, wheat, and soybean systems are commonplace in the mid-Atlantic U.S. region. These no-till systems feature less soil mixing than conventional tillage systems, and are susceptible to stratification of soil pH and relatively immobile nutrients, such as P. Traditional use of poultry litter (PL) also lends itself to stratification due to the concentration of P in PL. Applying PL at rates meant to satisfy crop N requirements can increase P concentrations in the soil surface beyond crop P requirements. Excess soil test P can lead to high P concentrations in agricultural runoff and increases nutrient leaching when the soil's P saturation point is reached (Moore and Edwards, 2007). Mixing alum (aluminum sulfate) into PL to produce PLA is a popular management practice to improve in-house conditions for poultry and also mitigate nutrient losses in runoff. Alum works by acidifying PL to form ammonium instead of ammonia, and by converting water-soluble P into less soluble aluminum phosphate forms. Previous research on tall fescue in conventionally tilled, silt loam soil (Moore and Edwards, 2005; 2007) suggested less leaching of soluble P from PLA than PL, more stratification of soil test P in the top 2 in., and that both could increase soil pH, PL more so than PLA.

Study Description

A long-term no-till two-year rotation was initiated in 2003 in Painter, Virginia on a Bojac sandy loam that consisted of a corn (summer) – wheat (winter) – soybean (summer) – fallow (winter) rotation. Fertilization included ammonium nitrate as a no-P control (34% N), inorganic P fertilizer (TSP; 46% P_2O_5), PL, and PLA. Nitrogen application was equalized across all treatments and was based on Bitzer and Sims (1988), assuming 80% inorganic N and 60% organic N was available to the current cash crop. Lime was not applied to any plot during the study so that the liming capabilities of PL and PLA could be monitored. The TSP treatment received inorganic P as soil tests suggested (Maguire and Heckendorn, 2011). Poultry litter and PLA treatments were applied at 2 t/A prior to planting wheat and 5 t/A prior to planting corn, resulting in P application rates presented in **Table 1**. Soil cores were collected by depth (0 to 2 in., 2 to 6 in., and 6 to 12 in.) in 2000, 2004, and 2011. Mehlich-1 extractable P was determined using the double acid method and pH was measured following Virginia Tech Soil Testing Laboratory procedures (Maguire and Heckendorn, 2011).

Soil pH (0 to 2 in.)

In 2000, prior to any treatments being applied, there were no differences in soil pH between land areas, which

Common N–based rates for poultry litter (PL) application in the mid-Atlantic region were tested over nine years to track changes in soil profile pH and P concentration. A common in-house best management practice of modifying P solubility by lowering PL pH with alum did little to prevent P build-up over time and did not reduce plant available P that would limit growth.

KEYWORDS:
poultry litter; alum; stratification; soil test phosphorus; soil pH.

ABBREVIATIONS AND NOTES:
N = nitrogen; P = phosphorus; K = potassium; $CaCO_3$ = calcium carbonate; triple super phosphate (TSP); Mehlich-1 extractable phosphorus (M1-P); ppm = parts per million; poultry litter (PL); poultry litter with alum (PLA).

IPNI Project USA-VA25

https://doi.org/10.24047/BC102221

Table 1. Phosphorus (P) application treatments for a continuous no-tillage corn-wheat-soybean rotation on a Bojac sandy loam on the Delmarva peninsula.

Season	Year	Crop	TSP†	PL‡	PLA§
			- - - - - - - - lb P/A - - - - - - - -		
Winter/Spring	2003/2004	Fallow	0	109	107
Summer	2004	Corn	0	0	0
Winter/Spring	2004/2005	Wheat	0	77	82
Summer	2005	Soybean	0	0	0
Winter/Spring	2005/2006	Fallow	0	88	104
Summer	2006	Corn	0	0	0
Winter/Spring	2006/2007	Wheat	0	55	61
Summer	2007	Fallow*	0	0	0
Winter/Spring	2007/2008	Fallow	0	0	0
Summer	2008	Fallow	0	0	0
Winter/Spring	2008/2009	Fallow	0	91	86
Summer	2009	Corn	0	0	0
Winter/Spring	2009/2010	Wheat	9	107	163
Summer	2010	Soybean	0	0	0
Winter/Spring	2010/2011	Fallow	0	111	89
Summer	2011	Corn	0	0	0
Total			9	638	692

†Triple superphosphate (TSP) treatment.
‡Poultry litter (PL) treatment.
§Poultry litter amended with alum (PLA) treatment.
*Plots were maintained without litter treatments till Summer 2009.

Table 2. Soil pH (0 to 2 in.) from four fertilizer regimes in a long-term no-till rotation on a Bojac sandy loam on the Delmarva peninsula.

Treatment	2000	2004	2011
	- - - - - - - - - - - - - - - - pH - - - - - - - - - - - - - - - -		
Control	6.2 a A†	6.3 c A	5.4 c B
TSP	6.1 a A	6.3 bc A	5.4 c B
Poultry litter (PL)	6.4 a B	6.6 a A	5.6 b C
Poultry litter + Alum (PLA)	6.2 a B	6.5 ab A	5.8 a C

†Means followed by different lower case letters within a column are significantly different ($p = 0.10$). Means followed by different upper case letters within a row are significantly different ($p = 0.10$).

averaged 6.2 (**Table 2**). Soil pH increased with PL and PLA applications between 2000 and 2004, most likely due to their $CaCO_3$ content. After several more years of study, acidity produced by applications of inorganic N fertilizers, acid rain, and soil microbial activity overcame the liming capacity provided by PL and PLA, and soil pH started to decrease by 2011.

Comparing treatments within a year, PL and PLA had similar soil pH in 2004, and were significantly higher than the control (**Table 2**). In 2011, soil pH with PLA and PL was higher than the control and TSP treatments. Little difference was noticed between the PL and PLA treatments. Although a liming effect was observed with PL and PLA in 2011, soil pH fell below the 6.2 target. Soil pH plays an important role in nutrient availability to plants as low pH can bind P and cause toxicity issues from aluminum and other elements.

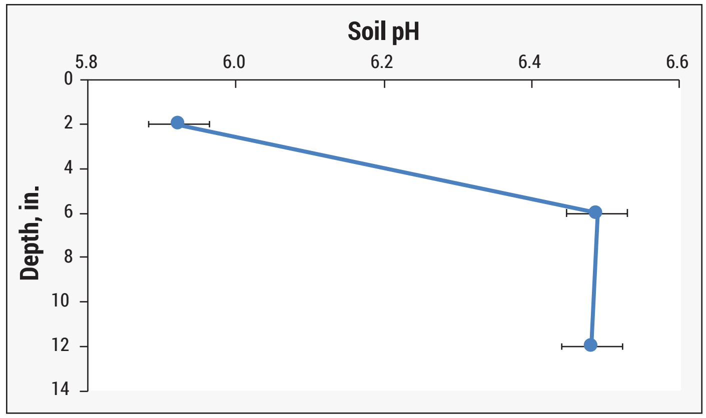

Figure 1. Soil pH (averaged over treatments) in 2011 ($LSD_{0.10} = 0.1$) by depth in a long-term no-till rotation on a Bojac sandy loam on the Delmarva Peninsula.

Soil pH (at depth)

In 2011, lower pH readings in surface soils versus subsurface soils demonstrated stratification due to no-till. The lack of soil mixing, yearly surface N applications, microbial activity, and acid rain all contribute to a decline in surface soil pH. However, no change in pH was observed below 2 in., which remained similar to the target pH of 6.2 (**Figure 1**).

Mehlich-1 Extractable Phosphorus (0 to 2 in.)

All soil test P values in 2000 were "Very High" for Virginia (>55 ppm P). In 2011, PL and PLA treatments were similar (157 and 141 ppm P, respectively), and were greater than the control and TSP treatments (62 and 67 ppm P, respectively) (**Table 3**). This difference demonstrates the potential for M1-P buildup with repeated application rates above crop removal, which are approximately 21, 18, and 29 lbs P/A for 90, 50, and 150 bu/A for wheat, soybean, and corn, respectively. Over time, a significant decrease in M1-P was observed in the control and TSP treatments, which was the first indication of P drawdown in the soil. Poultry litter and PLA application resulted in similar M1-P values in 2004 and 2011, indicating comparable availabilities regardless of the presence of alum.

As observed, "Very High" M1-P concentrations (>55 ppm P) can take years to reduce to concentrations where crops would be expected to respond to P applications. The control treatment experienced a decline of 3 ppm P/yr. At these rates, it will take 14 years to reduce M1-P concentrations to where fertilizer is needed. This is an economic benefit to growers, as they can forego P fertilizer applications in "Very High" P testing soils for many years without an

Table 3. Mehlich-1 extractable P (0 to 2 in.) from four fertilizer regimes in a long-term no-till rotation on a Bojac sandy loam on the Delmarva peninsula.

Treatment	2000	2004	2011
	ppm P		
Control	95 a A†	89 b A	62 b B
TSP	96 a A	92 b A	67 b B
PL	101 a B	139 a A	157 a A
PLA	88 a B	120 a AB	141 a A

†Means followed by different lower case letters within a column are significantly different (p = 0.10). Means followed by different upper case letters within a row are significantly different (p = 0.10).

expected reduction in yield.

Mehlich-1 Extractable Phosphorus (at depth)

Analysis of M1-P concentrations found stratification by depth. In 2011, PL and PLA treatments had very high M1-P concentrations at the 0 to 2 in. and 2 to 6 in. sample depths, which were significantly higher than M1-P concentrations of the TSP and control treatments at all depths. The significant difference between the control and PL/PLA treatments at 2 to 6 in. implies P leaching from the surface due to applied P exceeding plant uptake and the P sorption capacity of the sandy loam soils found on the Virginia coastal plain. It is interesting to note higher M1-P concentrations with PL applications as more P was applied with PLA over the system (638 vs. 692 lbs P/A for PL and PLA, respectively; **Table 1**).

Conclusions

Surface soil pH generally decreased over time; however, PL and PLA treatments resisted acidification. By 2011, all treatments had surface soil pH values below 6.2. Soil test P was greater with PL and PLA compared to control and TSP treatments in all years after the initiation of the study due to N-based manure applications that provided P rates above crop removal. Concentrations of M1-P at depth indicated P leaching in the PL and PLA treatments by 2011, with no P movement observed from TSP as P was only applied as required per soil tests. Overall, alum amendments to fresh PL had little effect after field application on crop yields but did reduce M1-P at depth. Surface concentrations of M1-P in the 0-P control did not fall below the agronomic threshold of 55 ppm P during the study, suggesting soils testing "Very High" may take over 10 years before additions of P fertilizer would benefit crop production. Overall, no visual differences were seen between sources regarding crop production so optimal best management strategies for bird health along with N and P management should be utilized in-house. **BC**

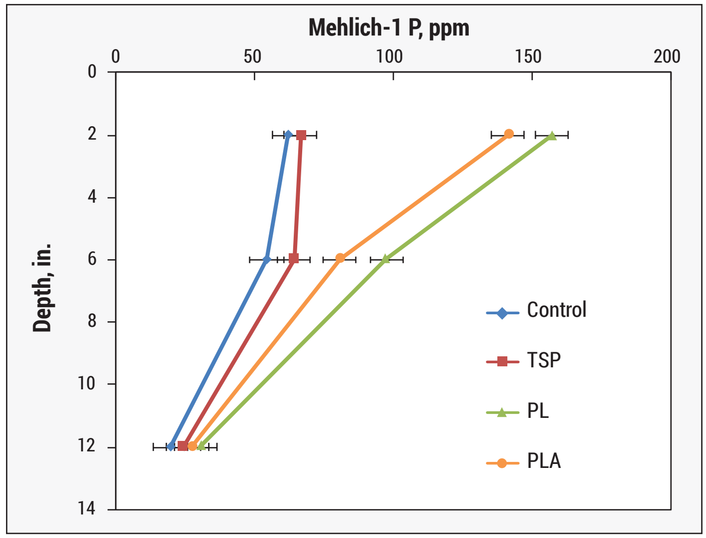

Figure 2. Mehlich-1 extractable P (M1-P) in 2011 ($LSD_{0.10}$ = 12) by depth from four fertilizer regimes in a long-term no-till rotation on a Bojac sandy loam on the Delmarva Peninsula.

TAKE IT TO THE FIELD

Amending PL with alum does not substantially reduce crop P availability, but may slightly alter overall P solubility in the system. Sustainable use of PL involves P-based rates when soil test P is already high, and using other sources to supply N in situations where surplus P is not required and could pose a risk of water contamination.

Acknowledgements

Funding for this work was provided in part by the Virginia Agricultural Experiment Station, the Hatch Program of the National Institute of Food and Agriculture, USDA, Maryland Grain Producers Association, and International Plant Nutrition Institute.

Ms. Fleming-Wimer is senior graduate assistant, Eastern Shore Agric. Res. Ext. Cntr., Virginia Tech, Painter, VA; Dr. Reiter is associate professor/extension specialist, Eastern Shore Agric. Res. Ext. Cntr., Virginia Tech; e-mail: mreiter@vt.edu. Dr. Maguire is professor/extension specialist, Dept. Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg, VA; Dr. Phillips is a director, IPNI North American Program, Owens Cross Roads, AL.

References

Bitzer, C.C. and J.T. Sims. 1988. J. Environ. Qual. 17:47-54.

Maguire, R.O., and S.E. Heckendorn. 2011. Virginia Cooperative Extension. http://www.soiltest.vt.edu/PDF/recommendation-guidebook.pdf (accessed 17 June 2013).

Moore, P.A., and D.R. Edwards. 2005. J. Environ. Qual. 34:2104-2111.

Moore, P.A., and D.R. Edwards. 2007. J. Environ. Qual. 36:163-174.