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Impact of Changing From Nitrogen- to Phosphorus-Based Manure Nutrient Management Plans

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Summary

Animal manures are a good source of nitrogen (N) and phosphorus (P) for agricultural crops, but they have an imbalance in their N to P ratio, so that if they are applied to meet crop N needs, then P is overapplied. For many years, manures have been applied to meet crop N needs, which has resulted in some soils containing more P than crops require, leading to environmental concerns. Regulations have been developed to limit P losses from manures and soils high in P by moving manure nutrient management from an N basis to a P basis.

A seven-year study was conducted at three sites in Virginia comparing N-based to P-based nutrient management of manures, and comparing poultry litter to commercial (inorganic) fertilizer. Six treatments were compared: (1) no P; (2) poultry litter applied on an N basis; (3) inorganic P, equal to the P applied in treatment No. 2; (4) poultry litter applied on an estimated annual crop P-removal basis; (5) inorganic P, equal to the P applied in treatment No. 4; and (6) poultry litter applied once every two or three years at a two-year or three-year crop-removal P rate. All treatments received the same rate of plant-available N, with inorganic N added where necessary.

Results showed:

- Yields were the same across all treatments – even the no-P treatment – as the soils supplied sufficient P, and all treatments received the same rate of N.
- Poultry litter had the beneficial effect of raising soil pH by an average of 0.2 relative to the inorganic fertilizer treatments (table 2).
- The N-based treatments (whether litter or commercial fertilizer) applied up to 783 pounds of P_2O_5 per acre in excess of crop removal in harvested portions of crops grown over the seven years (table 3). This clearly explains why soil-test P increases fairly rapidly under N-based manure nutrient management.
- Cropping with no-P additions was able to remove up to 446 pounds P_2O_5 per acre. After seven years, Mehlich 1 P was greatest in soils under the N-based treatments, smallest in the no-P treatment, and intermediate in the P-based treatments (table 4). For example, at the Shenandoah County site, Mehlich 1 P decreased by 35 parts per million (ppm) under the no-P treatment and increased by 36 ppm under the inorganic, N-based treatment. Changes in Mehlich 1 P over seven years varied by site, due to differences in soil properties and initial Mehlich 1 P.
- The results of this study show that soil-test P can be decreased in high-P soils over a few years by changing from an N-based to a P-based nutrient management plan or by stopping P applications totally, without negatively affecting yields.

Study Description

On-farm field trials were established in producer fields with a long-term history of animal manure applications and very high soil-test P ratings based on Virginia Tech's recommendations. Trials were conducted in Rockingham, Page, and Shenandoah counties. The Rockingham and Page sites were established in the spring of 2000 (Mehlich 1 P ranging from 86 ppm to 697 ppm), and the Shenandoah site was added in the spring of 2001. The study was concluded at the end of 2006, so there were seven years of data for the Rockingham and Page sites and six years of data for the Shenandoah site. The Rockingham site was in continuous corn for

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silage; the Page site was corn silage in 2000, rye (*Secale cereale L.*) then corn silage in 2001, orchardgrass (*Dactylis glomerata L.*) in 2002 to 2005, and millet (*Setaria italica*) in 2006; and the Shenandoah site was in corn for silage in 2001, then corn earlage (only the corn ear harvested) from 2002 to 2006.

The treatments were: (1) no P control; (2) poultry litter (broiler litter) applied on a N basis; (3) P as triple superphosphate, applied to equal the P applied in treatment No. 2; (4) poultry litter applied on an estimated annual crop P-removal basis; (5) P as triple superphosphate, applied to equal the P applied in treatment No. 4; and (6) poultry litter applied once every two or three years to supply the estimated two-year or three-year crop removal for P. All treatments received the same rate of plant-available N, with ammonium nitrate used as an inorganic N source to balance rates among plots. Supplemental potassium and/or lime were applied if needed, according to Virginia Tech's soil-test recommendations. More details on methods can be found in Maguire, Mullins, and Brosius (2008).

Results and Discussion

Initial Soil Properties of the Three Sites

Average site soil characteristics prior to initiation of the study are given in table 1. The soil texture ranged from a silt loam for the Frederick series in Rockingham County to a loam in Shenandoah and Page counties. The pH was slightly acidic, but within normal agronomic ranges at the Rockingham and Page sites, while slightly alkaline at the Shenandoah site, which is common for the Nomberville series formed in moderately fine textured alluvium. The OM content ranged from 2.2 percent to 3.0 percent, which is typical of soils in the Shenandoah Valley. No P is generally recommended for crops above a value of 55 ppm Mehlich 1 P (Donohue and Heckendorn 1994). The soils at all sites were above this concentration, ranging from 86 ppm at the Page County site to 696 ppm at the Rockingham County site, with the Shenandoah County site being intermediate at 344 ppm. The elevated Mehlich 1 P was almost certainly due to the intensive animal production in the region, which supplies more manure P than local crops require (Maguire, Crouse, and Hodges 2007).

Yields at the Three Sites and the Effects of the Treatments

Yields vary year to year due to complex factors such as timing and amount of rainfall, temperature, and planting date, in addition to soil-fertility status. When yields were compared across treatments, there were no significant effects or trends for the different treatments (figure 1). This was true for all three sites across all years of the study. This is what we would expect, as soil tests showed that all three sites had sufficient Mehlich 1 P for maximum crop growth. Therefore, producers should not worry about losing yield when they switch to a P-based manure management plan. However, we had to add supplemental commercial fertilizer N to make up for less N coming from manure in the P-based treatments, so producers need to keep this in mind.

Trends in pH

The Rockingham and Page sites had acidic pHs, while the Shenandoah County site was slightly alkaline (table 1). The pH increased under all treatments at the Rockingham site, possibly due to this site being limed without our knowledge (table 2). The pH decreased under all treatments at the Page site, while it changed little at the Shenandoah site. The pH was consistently higher for the litter treatments than the equivalent inorganic fertilizer treatments for all three sites. This is probably due to the liming effects of the poultry litter, as it has a pH of approximately 8.0 and contains substantial quan-

Table 1. Initial properties of the soils at the three sites. Mehlich 1 P calibration is Low: 0-6 ppm; Medium: 6-18 ppm; High: 18-55 ppm; and Very High: >55 ppm

County	Soil series	Texture	pH	OM	Mehlich 1 P
				%	ppm
Rockingham	Frederick	silt loam	6.3	3.0	696
Page	Braddock	loam	6.6	2.5	86
Shenandoah	Nomberville	loam	7.2	2.2	344

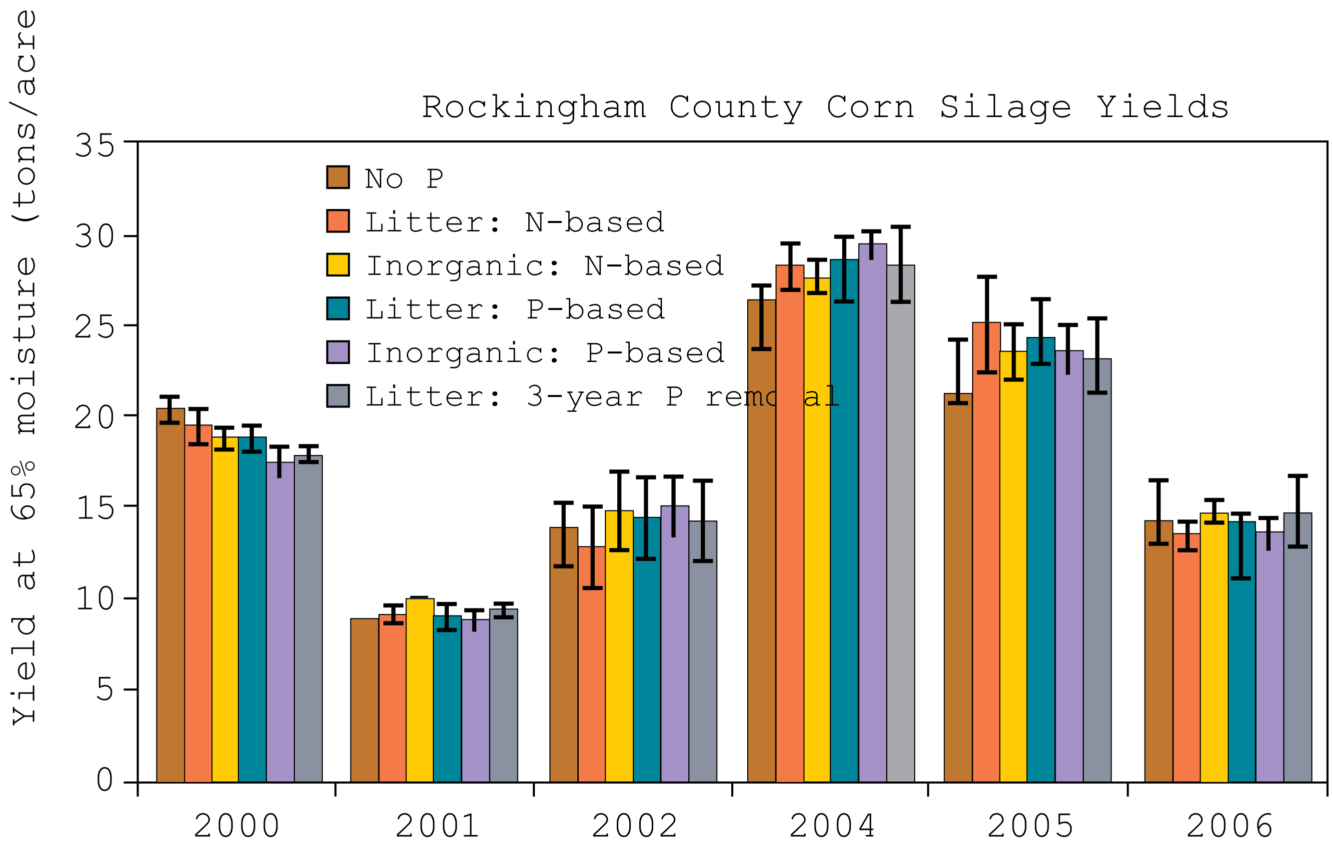

Figure 1. Annual corn silage yields at the Rockingham County site for the six treatments; error bars show range across the four replicated plots for each treatment

Table 2. Change in pH during the six years of treatments and cropping

	Change in pH					
	Rockingham		**Page**		**Shenandoah**	
No P	0.42	b	-0.90	c	0.05	a
Litter: N-based	0.61	a	-0.27	a	-0.10	ab
Inorganic: N-based	0.35	b	-0.83	bc	-0.22	b
Litter: P-based	0.61	a	-0.61	bc	0.03	a
Inorganic: P-based	0.45	b	-0.73	bc	-0.09	ab
Litter: 3-year removal	0.42	b	-0.77	bc	0.01	a

†Means within the same column followed by different letters are significantly different at the 0.05 probability level

tities of calcium carbonate. The inorganic N used was ammonium nitrate, which is acidifying to soils. As the recommended pH for most agronomic crops is about 6.0, the ability of litter to resist decreases of soil pH in acidic soils is a benefit over inorganic fertilizer.

Phosphorus Balances for the Sites During the Study

The P applied varied by crop and soil type, and the P removed also varied due to crop type and yield. We calculated the P balance by subtracting the P removed in the harvested portion of the crop from the P applied in manure and fertilizer. After six or seven years, the P balances showed either a large net input of P to the soils or a large net removal of P, with consistent trends across the treatments (table 3). As expected, after six or seven years, the lowest P balance was for the no-P treatment, with it removing 363, 446, and 418 pounds of P_2O_5 per acre at the Rockingham, Page, and Shenandoah sites, respectively. Among the treatments across all sites, the P balances increased in the order: no P was less than litter or inorganic (P-based), which was less than litter or inorganic (N-based). The P balances for the litter two-year or three-year removal treatments closely followed the annual litter or inorganic P-based treatments, as they applied similar amounts of P.

The P-based treatments were close to the balance they were designed to achieve, but were slightly positive as yields were short of expectations in some years, probably due to occasional unfavorable conditions such as late planting or insufficient rainfall. The N-based treatments all applied substantial surpluses of P compared to removal by crops, ranging from 376 pounds to 783 pounds of P_2O_5 per acre, over the six or seven years of applications and cropping. The greatest surpluses of applied P were at the Shenandoah site, where earlage was harvested instead of corn silage, which meant much less P removal. When comparing poultry litter to inorganic fertilizer, the P balances at the end of the study were very similar for these P sources, and there were no trends for a higher P balance from one source over the other.

Trends in Mehlich 1 P in the Soils

The changes in Mehlich 1 P over the six or seven years of the experiment were calculated by subtracting the initial Mehlich 1 P from the final Mehlich 1 P. As all treatments except the no-P treatment received regular applications of P in inorganic or litter form, it is not surprising that the no-P treatment had the lowest Mehlich 1 P of all the treatments after six years at all three sites (table 4). The scale of decrease in Mehlich 1 P in the no-P treatment varied by site and initial Mehlich 1 P (table 4). The Rockingham site was most variable due to the very high Mehlich 1 P, as a small percentage error in sampling and analysis could hide treatment-induced changes in Mehlich 1 P. For example, a 10 percent error in measuring the approximately 750 ppm Mehlich 1 P Rockingham soil is plus or minus 75 ppm. After six years, the no-P treatment at the Rockingham site had the lowest Mehlich 1 P relative to the other treatments, but the final Mehlich 1 P was 70 ppm greater than the initial Mehlich 1 P (table 4).

Table 3. Phosphorus balances (P applied minus P removed in harvested crop) for the three sites and six treatments

	Phosphorus balance					
	Rockingham		Page		Shenandoah	
Treatment	lbs P_2O_5/acre					
No P	-363	c	-446	c	-418	c
Litter: N-based	617	a	376	a	783	a
Inorganic: N-based	600	a	392	a	777	a
Litter: P-based	131	b	12	b	127	b
Inorganic: P-based	114	b	10	b	149	b
Litter: 3-year removal	117	b	112	ab	119	b

†Means within the same column followed by different letters are significantly different at the 0.05 probability level.

Table 4. Changes in Mehlich 1 P over the six or seven years of the experiment under the six different treatments, calculated as the final Mehlich 1 P minus the initial value

	Change in Mehlich 1 P					
	Rockingham		Page		Shenandoah	
	ppm					
No P	70	a	-40	c	-35	c
Litter: N-based	91	a	13	a	16	ab
Inorganic: N-based	143	a	6	a	36	ab
Litter: P-based	39	a	-11	b	-23	bc
Inorganic: P-based	48	a	-17	b	-15	bc
Litter: 2-year or 3-year removal	106	a	-23	b	-19	bc

†Means within the same column followed by different letters are significantly different at the 0.05 probability level.

It is possible that the change in sampling depth due to the Rockingham site changing to no-till in 2006 had some effect, but it is hard to know. Due to these errors in sampling, analysis, and change to no-till, there were no significant differences in Mehlich 1 P between the treatments at the Rockingham site after seven years. As the Mehlich 1 P was smaller at the Page and Shenandoah county sites, errors in sampling and analysis were smaller relative to treatment effects, and therefore, treatment effects were clearer.

For the Page and Shenandoah county sites, Mehlich 1 P decreased by 40 ppm and 35 ppm respectively, representing a decrease of approximately 47 percent for the Page site, but only 10 percent for the Shenandoah site (table 4). At both sites, Mehlich 1 P increased substantially for the poultry litter and inorganic fertilizer treatments that were N based – by as much as 36 ppm – due to large positive P balances (tables 3 and 4).

The Mehlich 1 P decreased for treatments that were P-based at the Page and Shenandoah sites, even though the P balances for these treatments were slightly positive. The decrease in Mehlich 1 P under P-based nutrient management is probably due to slow reactions in soils that can decrease the solubility and plant availability of P in soils. At all three sites after six years, the Mehlich 1 P in the two-year or three-year P-removal treatment was similar to the litter and inorganic P-based treatments. At all three sites, Mehlich 1 P was greatest after six years under inorganic N-based management, with litter P-based management coming in below this (table 4). The same was true for P-based applications, with the inorganic treatments having greater Mehlich 1 P after six years compared to equivalent poultry litter applications. However, due to slight differences in initial Mehlich 1 P, when we compared the litter to inorganic fertilizer treatments, there were no significant differences in the change in Mehlich 1 P under either the N-based or P-based application rates (table 4).

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References

Donohue, S. J., and S. E. Heckendorn. 1994. Soil test recommendations for Virginia. Virginia Cooperative Extension. https://www.soiltest.vt.edu/content/dam/soiltest_vt_edu/PDF/recommendation-guidebook.pdf.

Maguire, R. O., D. A. Crouse, and S. C. Hodges. 2007. Diet modification to reduce phosphorus surpluses: A mass balance approach. *Journal of Environmental Quality* 36:1235-1240.

Maguire, R. O., G. L. Mullins, and M. Brosius. 2008. Evaluating long-term nitrogen- versus phosphorus-based nutrient management of poultry litter. *Journal of Environmental Quality* 37:1810-1816.