Dec 2nd, 12:00 AM

Managing Manure Phosphorus

Bahman Eghball  
*University of Nebraska*

Brian J. Wienhold  
*U.S. Department of Agriculture*

John E. Gilley  
*U.S. Department of Agriculture*

Follow this and additional works at: [https://lib.dr.iastate.edu/icm](https://lib.dr.iastate.edu/icm)

Part of the [Agriculture Commons](https://lib.dr.iastate.edu/icm), and the [Agronomy and Crop Sciences Commons](https://lib.dr.iastate.edu/icm)

[https://lib.dr.iastate.edu/icm/1999/proceedings/5](https://lib.dr.iastate.edu/icm/1999/proceedings/5)

This Event is brought to you for free and open access by the Conferences and Symposia at Iowa State University Digital Repository. It has been accepted for inclusion in Proceedings of the Integrated Crop Management Conference by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
Managing Manure Phosphorus

Bahman Eghball
Assistant Professor
Department of Agronomy, University of Nebraska

Brian J. Wienhold, and John E. Gilley
Soil Scientist and Agricultural Engineer, USDA-ARS, Lincoln, NE

Manure, a renewable resource, contains nutrients that are needed for plant growth. Phosphorus in manure can be utilized for crop production as a substitute for synthetic fertilizers. Phosphorus in manure can also be a source of surface or ground water contamination if not used properly. Increased P concentration can lead to eutrophication of surface waters. Management systems need to be developed to utilize manure P effectively without adverse effects on the environment.

Phosphorus in Manure

Each year, about 463,000 tons P is generated in swine operations, 244,000 tons in poultry houses, 173,000 tons in beef cattle feedlots, and 140,000 tons in dairies in the U.S. The amount of P generated in these operations can substitute for 56% of the total P fertilizer used each year in the U.S. (1,835,000 tons P). In addition to P, manure also contains N, K, micronutrients and organic matter. The organic matter in manure may be more valuable than nutrients it contains when manure is applied to less productive sites within a field or to degraded land (Eghball and Power, 1994).

Several factors affect mineral composition of manure including animal size and species, housing and rearing management, ration fed, manure storage, and climate. Phosphorus is primarily contained in the feces (>90%) and only traces are excreted in the urine, while most of the K (~70%) is excreted in the urine (Safley et al., 1985). Phosphorus loss during storage or treatment is minimal since P is not subject to volatilization and almost all of the loss occurs as a result of runoff. In lagoons, P is accumulated in the bottom sludge and only traces are found in solution.

Plant Availability of Manure P

In two studies in Nebraska, we determined plant P availability by sampling the top 6 inches of soil before beef cattle feedlot manure or compost was applied in 1992 and after application in the autumn of 1993. Soil bulk density was determined in 1993 and the amount of P released was estimated based on soil P concentration (Bray and Kurtz No. 1 P), soil bulk density, and the plant P uptake in 1993. In our N and P-based manure and compost application study, there was great variability for plant P availability from manure and compost (Table 1). Average across treatments, P availability was 85% of applied manure P and 73% of applied compost P in the first year after application. Phosphorus availability in the manure/tillage study, was 69% of applied manure P and 63% of applied compost P in the first year after application. Across experiments, first year P availability was 82% from beef cattle feedlot manure and 71% from composted feedlot manure (Table 1). Phosphorus in swine manure is expected to be more plant available than beef cattle manure since a greater portion of the swine manure P is water-soluble. For practical purposes, P in swine manure can be assumed to be 100% plant available.
Table 1. First year P availability from beef cattle feedlot manure or compost application in Nebraska.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Phosphorus Availability</th>
<th>N &amp; P-based study</th>
<th>Tillage/Manure study</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure for N</td>
<td></td>
<td>113</td>
<td>69</td>
<td>Manure = 82</td>
</tr>
<tr>
<td>Manure for P</td>
<td></td>
<td>57</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Manure for N / 2 y</td>
<td></td>
<td>71</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Manure for P / 2 y</td>
<td></td>
<td>98</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Compost for N</td>
<td></td>
<td>57</td>
<td>63</td>
<td>Compost = 71</td>
</tr>
<tr>
<td>Compost for P</td>
<td></td>
<td>71</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Compost for N / 2 y</td>
<td></td>
<td>113</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Compost for P / 2 y</td>
<td></td>
<td>52</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Phosphorus in manure tends to be more available to plants than compost P since manure P is converted to less soluble compounds during composting. The high P availability from manure and compost indicates that these resources can be used similar to synthetic P fertilizers.

**Practices for Reducing Manure P Content**

**Phytase and highly available P corn:**

Phosphorus contained in feed grains is present largely in an organic form called phytate or phytic acid. In order to be utilized by animals eating the grain, inorganic P must be enzymatically cleaved from the phytate molecule. The enzyme that cleaves phosphate from the phytate molecule is phytase. Phytase is a microbially produced enzyme. Ruminants have microbes in their digestive tracts that produce phytase and P contained in phytate is largely available to these animals. Monogastric animals such as poultry and swine lack the associated microbes and feed grain P is less available to these animals. To compensate for this low availability, diets for monogastric animals are commonly supplemented with inorganic P. Supplementation represents an additional input cost for producers. The low utilization of organic P results in high P content of manure. The two strategies that are available for increasing utilization of feed grain P are supplementing diets with microbially produced phytase and developing feed grains that store P in more available forms.

Microbially derived phytase has been commercially available as a diet additive for several years. Phytase supplementation of swine diets has been shown to increase P availability from 15% in unsupplemented diets to 43% in supplemented corn-soybean diets (Cromwell et al., 1993). As a result of 24% greater availability of P with phytase supplementation, a 35% reduction in manure P content was observed (Simons et al., 1990). When added to low P broiler diets, phytase increased P availability by 60% and reduced the P content of manure by 50% (Simons et al., 1990). By improving availability of phytate P, phytase supplementation reduces the amount of inorganic P that must be added to the diet to meet animal needs. Phytase supplementation becomes economically practical when the cost of meeting the P needs of the animal using
phytase supplementation becomes less than the cost of meeting the P needs of the animal using inorganic P supplementation.

A gene that reduces the phytate P content without reducing the total P content in corn grain was recently isolated (Ertl et al., 1998). Several seed companies have purchased the rights to incorporate this trait into their commercially available hybrids. Highly Available Phosphorus (HAP) corn will be available to producers within one-to-three years. Recent research has demonstrated that swine fed HAP corn with no additional P exhibited greater daily gains, greater daily gain: daily feed intake ratios, and greater bone strength than pigs fed conventional corn supplemented with P. Bioavailability of P in HAP corn was 64% compared to 10% in conventional corn. The increased bioavailability resulted in greater P digestibility, greater P retention, and a reduction in P excretion. Reduced P excretion resulted in an increase in the N:P ratio of the manure (Spencer et al., 1998). Similar results were obtained by Pierce et al. (1998) who reported that bioavailability of P for traditional corn was 22% compared to 77% for HAP corn, swine fed HAP corn had greater average daily gains and bone strength, and P excretion was reduced. Phosphorus availability to chicks fed diets containing HAP corn was 70% and chicks fed a traditional corn diet was less than 40% that of an inorganic P supplemented corn diet (Ertl et al., 1998). Fecal P content in chicks fed a HAP corn diet was 45% less and chicks fed a traditional corn diet was 30% less than that of chicks fed an inorganic P diet (Ertl et al., 1998). Research with HAP corn has demonstrated that using HAP corn as part of the diet without compromising animal performance can reduce manure P content. Economic acceptance of this practice will depend on seed costs and any expenses incurred during storage (cost of separating and processing HAP corn from traditional corn).

Alum application:

Alum (aluminum sulfate) has been used in poultry houses to reduce ammonia loss. Ammonia loss can cause air pollution in the poultry houses and create an unsafe environment for the birds and the people attending them. Application of alum at the rate of one ton per 10,000 birds between flocks significantly reduced poultry litter soluble P concentration and a subsequent 70% reduction in runoff loss of dissolved P (Shreve et al., 1995). The reaction of aluminum sulfate with P in manure would result in the formation of aluminum phosphate, which is less water-soluble. Alum cost is about $220 per ton.

Manure P Application Strategies

Manure application for nutrient management can be made based on several strategies, i.e. N-based, P-based, annual, biennial, etc. Manure is an unbalanced fertilizer in that P is applied in excess of plant requirements when manure application is made to provide for plant N requirements. Application of manure to provide for crop N requirements can greatly increase soil levels of P and other ions. This is because the N:P ratios of most manure types are significantly smaller than N:P uptake ratios of most crops. The N:P ratio was 2.6 for feedlot manure and 1.9 for composted manure (Eghball et al., 1997) while N:P grain uptake ratios of winter wheat, corn, and grain sorghum were 4.5, 5.9, and 4.5, respectively (Gilbertson et al., 1979). Eghball and Power (1999) found that P-based beef cattle feedlot manure or compost application resulted in similar corn grain yield to those for the N-based or fertilizer applications but with significantly less soil P levels. The soil P level following 4-yr of P-based manure or
Compost application was similar to the original soil P level before initiation of the study. Nitrogen-based manure or compost application resulted in soil P levels greater or equal to 150 ppm (Bray and Kurtz No. 1) after 4-yr of application. Manure application based on crop P requirements will increase the required land area. Site-specific conditions (cropping systems, tillage, conservation practices, etc.) should be considered when N or P-based strategies are used. P-based application needs to be used in areas where soil P level is high or excessive and/or potential for P loss is great.

Runoff or Leaching Losses of P

Phosphorus can leach into the soil following heavy or long-term application. Eghball et al. (1996) found that P from manure moved deeper into the soil than P from commercial fertilizer at similar application rates. Possible explanations are that P from manure moved in organic forms, or chemical reactions of P occurred with compounds in manure, which may have enhanced P solubility. P leaching into surface waters in areas with tile drains or in deep sandy soils can be a significant contributor to P pollution (Sims et al., 1998).

Even though P can leach into the soil, the primary concern about P pollution has been the P runoff losses. Surface application of manure may result in more runoff P loss than when manure is injected or incorporated by tillage operation. Eghball and Gilley (1999) found that incorporating manure or compost resulted in less loss of dissolved P but in greater loss of total P than surface-applied manure or compost. This was because of greater soil erosion when soil was tilled and the close relationship between total P loss and soil erosion. A single switchgrass hedge (3 feet wide) resulted in 50% reduction in P loss from a soil with 12% slope and receiving beef cattle feedlot manure and fertilizer near Treynor, Iowa (Eghball et al., 2000).

Table 2. Influence of selected variables on runoff losses of total and dissolved P in three experiments receiving manure, compost, and fertilizer application in no-till and tilled systems and located in eastern Nebraska and western Iowa.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total P</th>
<th>Dissolved P</th>
<th>Partial R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion</td>
<td>0.80</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Runoff</td>
<td>0.05</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>Bray and Kurtz No. 1 soil P (0 – 2 in)</td>
<td>0.02</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Applied P</td>
<td>0.01</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Source†</td>
<td>-</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Tillage</td>
<td>-</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Erosion X Runoff</td>
<td>-</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.88</td>
<td>0.72</td>
<td></td>
</tr>
</tbody>
</table>

†Sources were cattle feedlot manure, composted manure, and fertilizer; tillages were disked and no-till systems. Bray and Kurtz No. 1 soil P for the three sites were 31, 76 and 83 ppm in the top 2 inches.

The dashes indicate that the factor had a probability level > 0.50.
Recently, a risk assessment index has been proposed by Lemunyon and Gilbert (1993) that incorporates both the transport (runoff, erosion) and source factors (soil test, P application rates and methods) to assess the vulnerability of a particular site to P runoff losses. Sharpley (1995) found close correlation between the index rankings and the amount of total P loss from various watersheds. Three rainfall simulation studies were conducted in eastern Nebraska and western Iowa and the sites received beef cattle feedlot manure, composted manure, and fertilizer application under no-till and disked systems (Eghball and Gilley, 1999; Eghball et al., 2000). In these studies, erosion was found to be the important factor in total P loss while runoff was a key factor in runoff loss of dissolved P (Table 2). A close correlation (r=0.74) was observed between the P index rankings and the total P loss in these experiments. Actual soil erosion was used to determine the P index rankings.

Summary

Manure is an excellent source of P that can serve as a substitute for synthetic fertilizer. High plant availability of P makes manure an ideal P source for crop production. In addition to P, manure also contains other N, K, micronutrients, and organic matter. Including phytase enzyme in the diet can significantly reduce P content of poultry and swine manure. Diets containing highly available P corn can significantly reduce manure P content in all livestock species. Addition of aluminum sulfate (alum) to manure in poultry houses has been shown to reduce ammonia loss and decrease soluble P content of manure. Nitrogen-based manure or compost application strategy can be used in soils with low P levels or those with little potential for P runoff losses. Phosphorus-based application should be made when soil P level is high or excessive and/or the potential for P runoff losses is great. Erosion is an important factor in runoff total P loss from a field. Any management system that reduces erosion will reduce total P loss. When erosion is controlled, runoff and soil test become important factors as these will influence runoff loss of dissolved P.

References


