PHOSPHORUS DYNAMICS OF LAND-APPLIED COMPOST BEDDED PACK DAIRY BARN PRODUCT IN LOW AND HIGH SOIL TEST PHOSPHORUS ENVIRONMENTS

Leslie Hammond, Mark Coyne and Joseph Taraba
The University of Kentucky

Abstract

Characterizing and understanding the nutrient dynamics of land applied compost bedded pack dairy barn (CBP) products is necessary because this waste management system and its fertility use are increasingly common. An aerobic mineralization study was conducted to observe the phosphorus (P) dynamics of land-applied CBP product in low and high soil test P (STP) environments. An innovative phosphorus fractionation strategy employing UV-assisted organic P decomposition helped quantify fractions corresponding with nutrient availability, which revealed the forms of P most likely to leach or be bio-available, and the forms that would be fixed or recalcitrant. The CBP material, no matter the rate, increased the water-soluble P and total P of both low and high STP soils at the time of addition. The extractable P was proportional, but not uniformly proportional, to the addition of P at the time of application regardless of rate. With time, the distribution of each P fraction changed such that P became more abundant in organic fractions after 30 days in both low and high STP soil environments, particularly at the higher application rates. With time, any addition of P, regardless of rate, in each of the soil types should increase STP. The study is continuing and the final change in each of the fractions of P in soil is yet to be determined for longer incubation periods.

Introduction

Compost dairy barns were first adopted in the United States around 2006. Nearly ten percent of Kentucky dairies currently utilize this system, which is thought to be geographically and scale appropriate for small to mid-size dairies in the upper south (Taraba et al., 2012) The housing system has two separate distinct areas: the feed alley and the loafing area, the latter, is composed of a carbon- rich base such as saw dust or woodchips (Fig. 1). In the loafing area, where composting occurs, the wastes are converted *in situ* into a solid organic waste amendment. As waste accumulates, more bedding is applied to maintain a safe and clean loafing area for the cows. Twice daily, the bed is aerated by tillage to facilitate composting and to maintain a clean and safe surface on which cows may loaf. The task of handling manure is made easier when it is converted from a liquid waste into a solid soil amendment (Pecchia, 2013). Recovered wastes are either stored for further processing or land-applied as a supplemental fertilizer.

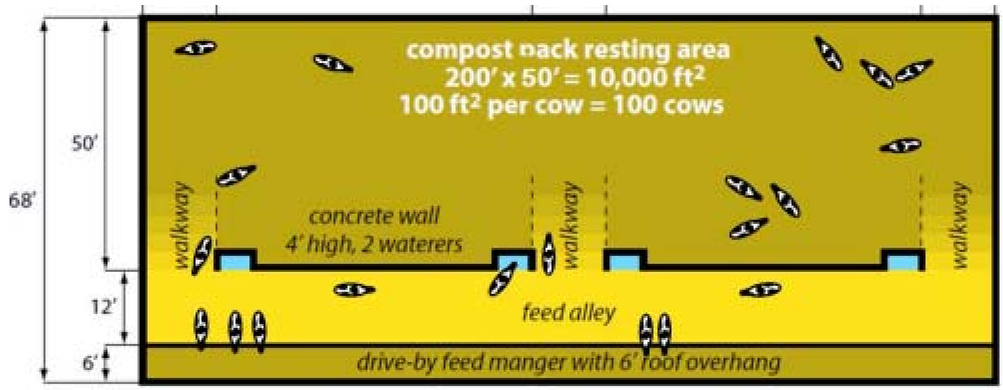

Figure 1. Schematic of a typical compost bedded pack dairy system (Bewley et al., 2013).

In general, mature compost stabilizes nutrients into biomass, thereby slowing down nutrient release. Compost used as a soil amendment enhances soil productivity and increases soil organic matter, and can aid in mitigating leaching of nutrient rich wastes (Dick et al., 1993). Little is known about the fertility release aspects of CBP product, which contains approximately 2% N and 0.5% total P, because it is not considered a "mature" or "finished" material. Preliminary data suggests that nutrient availability is affected by barn management. Well-managed barns tend to have more predictable release characteristics and more potential nutrient availability as the material becomes more nutrient dense with time. Data also suggests that approximately 10-20% of the N and 60% of total P in the CBP material is plant available in the first growing season. These nutrient availability data are less than the predicted values used by nutrient management planners.

Researchers concluded that CBP material is unpredictable and should be used in moderation to supplement N needs (Russelle et al., 2009). Russelle et al.'s study implied that management affects nutrient availability, which was confirmed by our preliminary studies, but not in a field setting. Limited information is available regarding the nutrient availability of CBP material in relation to P. Among the information yet to be determined are P dynamics of amendments in relation to STP. Of upmost importance is addressing the P dynamics of the CBP product because producers utilizing this product are often subject to nutrient management guidelines by regulatory agencies that require fertilization rates based on P rather than N. Due to the variety of inorganic and organic P compounds in soils, and the inability to adequately measure and estimate microbial transformations within this complex, measurement of P availability with respect to organic P availability is a difficult analytical technique.

Nutrient applications for P depend on a P-index, which is based on several parameters such as slope, vegetation, method of application, and the STP values of the soil. At certain STP values, it is hypothesized that P loading to soils increases the risk of pollution to surface and ground waters. Animal feeding operations often apply on an "N-basis" to meet yield goals, which consequently leads to over application of P. In the high STP environments of sensitive soils this can increase the risk of pollution.

Objectives

The objectives of the study were to examine the effect of CBP application rate and initial STP on changes in P speciation with time. Additionally, we explored a simple P fractionation technique and utilized that technique to observe the P dynamics of land-applied organic waste amendments. This report focuses on the results of that P fractionation technique for the first 30 days of aerobic incubation of CBP material.

Approach

Two representative soils were used to observe the effect of differing soil test P values on the change in soil test P with time after amendment with different organic amendments. The amendments used included raw dairy manure and CBP product originating from the same herd at the same time. This report addresses only the CBP material.

Soil Processing

Two soils of the same series (Faywood- fine, mixed, active, mesic Typic Hapludalf) that exhibited differing initial STP values, but similar mineralogy were collected from the central Bluegrass area of Kentucky. Neither soil had undergone any fertilization besides a light liming a few years previously. Both soils occupied the same landscape position on a similar slope, with cool-season grass vegetation in a pasture setting. Samples were taken from the top 15 cm of soil and mixed to form a composite. The soils were air-dried and sieved to 2 mm. The samples were brought to optimum moisture for biological activity (60-65% water-filled pore space) and five replicate 100 g samples were placed into clean plastic bags for each treatment for each designated collection.

Initial STP values were determined for each soil. The values were determined by Mehlich III extraction. Initial STP values of the Faywood with low STP were 14.6 mg kg^{-1} and 177.8 mg kg^{-1} for the high STP soil. The water pH of the low STP and high STP soils were 6.6 and 6.0 respectively. The clay content of the low STP soil was 27% and the high STP soil was 22%. The higher clay content of the low STP soil could partially account for the lower STP value. The organic matter of the soils was approximately equivalent at 1.76% and 1.98%, respectively.

Amendments

Compost bedded pack dairy barn product was collected from Harvest Home Dairy in LaGrange KY. Researchers who have been working with approximately 80 cooperators with CBP barns in the state consider this site to have ideal management (Bewley et al., 2013). The CBP product samples were taken as core samples from nine distinct areas in the barn. The CBP product samples were mixed to form a composite and air dried. After air drying, the samples were sieved to 2 mm to increase homogeneity. Samples were stored at 4º C until use.

Total P of the amendment was determined by ICP and Kjeldahl digestion. The soluble P was determined colorimetrically using a malachite-green procedure. Application rates were determined on a mass basis as total P and were set at 0, 56, 112, and 224 kg P ha^{-1} (0, 50, 100, and 200 lb ac^{-1}).

Each soil was amended as required by treatment and placed into an incubator at 25 º C. Samples were collected at 30 day intervals. At the time of amendment, an initial fractionation of each sample was performed to obtain baseline data. At each collection date, STP was determined by Mehlich-III method and the Olsen-P method. Preliminary P-fractionation experiments using North American Proficiency Testing (NAPT) soils showed that the procedure best correlated to Olsen P (R^2=0.96).

The fractionation procedure employed a 1:100 dilution of soil to water stirred for four hours. Preliminary studies using NAPT soils revealed that a similar approach by Ron Vaz (1992) was not sufficient at extracting the desired P fractions in totality because the solutions were too concentrated. After mixing, solutions were transferred to cluster tubes and centrifuged at 3700 rpm for 27 min, which is equivalent to 45ɥm filtration. Phosphorus was determined after complexation of malachite green with phosphomolybdate in acidic conditions. The procedure was repeated after an additional step using a UV microplate and a 6 watt UV lamp to release organically bound P (Aminot and Kerouel, 2001); the difference in the latter and former procedure is considered the organic P fraction.

Results and Discussion

The amount of dissolved P from the inorganic and organic P fractions in the low STP soil ranged from about 5 to 84 mg/kg after amendment (Table 1). As expected, there was a consistent increase in both inorganic P and UV-P as the CBP rate increased, with inorganic P comprising the greatest fraction of the extractable P and comprising a greater fraction as the amendment rate increased.

Table 1. Initial P fractions in low STP soil amended with varying amounts of CBP Product.

	PPM P (mg/kg)		
Rate (kg/ha)	**PO_4-P**	**UV- P**	**Organic P[1]**
0	**7.1**	**12.6**	**5.5**
56	**25.7**	**30.2**	**4.5**
112	**47.1**	**53.2**	**6.1**
224	**74.9**	**84.0**	**9.1**

[1]Organic P is the difference between UV-P and PO_4-P and represents the UV oxidizable organic P fraction.

There was a slight increase in organic P from the initial extraction to the day 30 extraction of the low STP soil except for the unamended sample (Table 2). The proportion of inorganic P to organic P relative to amendment rate decreased with time, and for each amendment rate the amount of inorganic P decreased in general. For the 56 and 112 kg/ha application rates, a substantial amount of P was not recovered during the fractionation procedure. We hypothesize that some of the soluble P pool became unavailable by clay fixation. The observations support the conclusions of Thom et al. (2002) that there is little change in low STP environments in available P forms with the addition of P fertilizer, unless rates are high. In relation to this study, this could be due to the higher clay content of the soil, which would buffer change. Furthermore, the mechanism leading to the decrease in available P could be due to fixation to clay colloids as hypothesized previously.

Table 2. P fractions in low STP soil amended with varying amounts of CBP material after 30 days incubation.

	PPM P (mg/kg)		
Rate (kg/ha)	**PO_4-P**	**UV- P**	**Organic P**
0	**7.5**	**12.4**	**4.9**
56	**11.0**	**17.3**	**6.3**
112	**25.5**	**34.8**	**9.3**
224	**67.9**	**80.2**	**12.3**

[1]Organic P is the difference between UV-P and PO_4-P and represents the UV oxidizable organic P fraction.

The initial concentrations of inorganic and organic P ranged from approximately 2 to 193 in high STP soil (Table 3). The PO_4-P increased with rate, as expected, but decreased with time at the highest CBP application rates. Organic P values increased with time, particularly at the highest application rates (Table 4). As a consequence, although inorganic P comprised the great majority of P in the high STP soil originally, at the highest CBP rates its contribution were substantially reduced. This implies transition in the system to immobilized P, which may have regulatory implications. With the use of CBP in high STP environments, the form of P that is subject to leaching or erosion losses differs.

Table 3. Initial P fractions in high STP soil amended with varying amounts of CBP material.

	PPM-P (mg/kg)		
Rate (kg/ha)	**PO_4-P**	**UV-P**	**Organic P**
0	**48.3**	**50.9**	**2.6**
56	**69.4**	**73.5**	**4.1**
112	**103.4**	**105.8**	**2.4**
224	**193.3**	**195.0**	**1.7**

[1]Organic P is the difference between UV-P and PO_4-P and represents the UV oxidizable organic P fraction.

Table 4. P fractions in high STP soil amended with varying amounts of CBP material after 30 days incubation.

	PPM-P (mg/kg)		
Rate (kg/ha)	**PO_4-P**	**UV-P**	**Organic P**
0	**58.7**	**60.4**	**1.8**
56	**71.8**	**72.2**	**0.4**
112	**83.0**	**107.6**	**24.7**
224	**129.2**	**192.5**	**63.3**

[1]Organic P is the difference between UV-P and PO_4-P and represents the UV oxidizable organic P fraction.

Summary

With improved understanding of the fertility dynamics of land applied CBP material, we will be able to devise application recommendations that can be used by farmers, nutrient management planners, regulatory officials, and extension personnel. Such recommendations will adhere to the current nutrient management policies and regulations to which animal feeding operations are subject.

The P fractionation procedure utilized was best correlated with Olsen-P values for each NAPT soil. It is interesting to note that the initial amount of water soluble inorganic P extracted for each 56 kg increase in CBP-P slightly increased in the low STP soil while for the high STP soil the increase per unit CBP-P added was much greater. This observation, along with the observation that a greater fraction of the P was converted to organic P in the high STP soil, points to the significance of starting STP as a factor in assessing P decomposition dynamics of soils amended with various wastes.

Limited crop-response based on various STP parameters may limit the application of such methodologies to the field setting. Given the limitations of these procedures, the proposed P fractionation procedure should be recalibrated with a field study in the future. Ultimately, it is the intent of the researchers to take the P dynamics study to a field setting in pasture and cropping environments to provide more accurate recommendations about the nutrient availability indices of organic amendments.

References

Aminot, A. and R. Kerouel. 2001. An automated photo-oxidation method for the determination of dissolved organic phosphorous in marine and fresh water. Marine Chemistry 76:113-126.

Bewley, J., J. Taraba, and G. Day. 2013. Compost bedded pack barn design features and management considerations. University of Kentucky Cooperative Extension Service, Nov. 2012. Web. 12 Nov. <http://www2.ca.uky.edu/agc/pubs/id/id206/id206.pdf.

Dick, W.A. and E.L. McCoy. 1993. Enhancing soil fertility by addition of compost. p. 622-644. *In*: Hoitink, H.A.J. (ed) Science and engineering of composting: Design, environmental, microbiological and utilization aspects. Renaissance Publications, OH .

Pecchia, J. 2013. Effects of straw, sawdust and sand bedding on dairy manure composting. *http://www.cals.ncsu.edu/*. North Carolina State University, Ohio State University, n.d. Web. 11 Nov. 2013. <http://www.cals.ncsu.edu/waste_mgt/natlcenter/sanantonio/Michel.pdf>.

Ron Vaz, M.D. 1992. Determination of dissolved organic phosphorous in soil solutions by an improved photo-oxidation procedure. Talanta 39:1479-1487.

Russelle, M. P., K.M. Blanchet, G.W. Randall and L.A. Everett. 2009. Characteristics and nitrogen value of stratified bedded pack dairy manure. Online. Crop Management doi:10.1094/CM-2009-0717-01-RS.

Taraba, J., et al. 2012. Compost bedded pack barn design, features and management considerations. University of Kentucky Cooperative Extension Service. Nov. 2012 http://www2.ca.uky.edu/agc/pubs/ID/ID206/ID206.pdf

Thom,W. and J. Dollarhide. 2002. Phosphorus soil test change following the addition of phosphorus fertilizer to 16 Kentucky Soils. University of Kentucky Cooperative Extension Service. Vol. 34 No. 2. Web. http://www.uky.edu/Ag/Tobacco/agr_notes/agvl34_2.pdf

PROCEEDINGS OF THE

44th

NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 30

November 19-20, 2014
Holiday Inn Airport
Des Moines, IA

PROGRAM CHAIR:

James L Camberato
Purdue University
915 W State St.
West Lafayette, IN 47907
(765) 496-9338
jcambera@purdue.edu

PUBLISHED BY:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page**: www.IPNI.net**

ON-LINE PROCEEDINGS:

http://extension.agron.iastate.edu/NCE/