

CHAPTER 4

MINERALIZATION OF PHOSPHORUS FROM VANCE SOIL AMENDED WITH POULTRY LITTER-YARD WASTE COMPOST

ABSTRACT

Incubation studies were conducted on Vance sandy loam and on sand to investigate the rate of P mineralization from poultry litter-yard waste compost (PYC). Poultry litter and YW were applied at the rate of 26.2 mg kg⁻¹, while PYC was applied at the rates of 17.5 and 26.2 mg kg⁻¹. The mixtures were incubated at 25⁰ C for 56 days. There were differences in amounts of P mineralized with treatment and with length of incubation. Extractable P in soil at the application rate of 26.2 mg P kg⁻¹ ranged from 8.2 to 11.9 mg P kg⁻¹ with PL, from 0.5 to 1.2 mg P kg⁻¹ with YW, and from 5.9 to 7.3, 4.3 to 5.1, and 6.4 to 7.3 mg P kg⁻¹ for PYC from 15:1, 20:1, 25:1 C:N ratio substrates. At the application rate of 17.5 mg P kg⁻¹, the extractable P in soil ranged from 3.6 to 4.4, 2 to 3.8, and 3.4 to 5.2 mg P kg⁻¹ with PYC from 15:1, 20:1, 25:1 C:N ratio substrates.

The soil equilibrated with PL and 25:1 C:N ratio PYC had an initial P immobilization followed by mineralization, while YW, and 15:1 and 20:1 C:N ratio PYC had a mineralization trend at 56 days. The sand-compost mixture had more extractable P than the Vance soil at equal levels of PL, YW, and PYC application. Adsorption of mineralized P by soil components probably was responsible for the difference in the rate mineralization. The PL had the highest rate of mineralization as compared with YW and PYC. All of these treatments were in the range at 26.5 mg P kg⁻¹ application which is needed to sustain the plant growth on the Vance soil.

4-1 INTRODUCTION

Investigations have been conducted to examine the physicochemical benefits of soil that accompany organic waste application (McConnell, 1993; Tester, 1990). As an example, mineralization of organic P to inorganic P increases P availability in soil and thereby increases crop yields on soils with low levels of labile P (Haynes, 1982). Mineralization of organic P has been considered to be too slow at the early mineralization stage to be significant in plant nutrition (Tester et al., 1990). They speculated that P in some organic forms may mineralize slowly. Phosphorus release from an organic waste increases with long term mineralization as microbial activity increases and, hence, more P becomes available to plants with time (Bitzer and Sims, 1988; Sims, 1986). Conversely, Taylor et al. (1978) stated that the P transformation occurs rapidly after application and that the mineralized P undergoes immobilization.

A variable portion of the P released from organic sources is sorbed by soil constituents such as silicate clay minerals or Al and Fe oxides (Olsen and Khasawneh, 1980). As a result compost is applied in large quantities to supply adequate P to accelerate the plant growth. The long term benefits of mineralization will be determined largely by the rate at which P is mineralized and the interaction of P with soil constituents.

The objectives of this experiment were to investigate the rate of P mineralization from PYC in Vance soil and to determine the relationship between P mineralization and three C:N ratios of substrates used in preparation of composts.

4-2 MATERIALS AND METHODS

4-2.1 Composting process

Three types of compost based on the pre-digestion C:N ratios were prepared for this experiment. Yard waste containing leaves and woody materials and PL were used in the preparation of the composts. The PL used in the mixture was collected from the poultry house

floor in a local area before composting. The substrates for the PYC were mixed at three C:N pre-composting ratios of 15:1, 20:1, and 25:1. The PL and YW were appropriately balanced to prepare the three different composts. For example, about 899 kg of fresh PL was mixed with 463 kg of YW, and moistened to 45 to 50% with tap water to obtain a C:N ratio of about 15:1, which is considered by Lynch (1993) as an optimum ratio for composting.

A wooden container which measured 1.21 m long, 1.21 m wide and 1.21 m high was constructed for each of the three PYC from the different C:N ratio substrates used in this experiment. The volume of the wooden container was approximately 1.81 m³. The materials to be composted were layered in the wooden container with a front end loader and water was added to each successive layer to attain a moisture content of approximately 50% (Brake, 1992). Compost containers were covered with plastic to avoid extra water from precipitation. Contents of the wooden container were turned as the temperature of the center of the pile dropped below 60° C. The composting was completed after a 4 months period. The final elemental composition of composted waste is shown in Table 4.1.

4-2.2 Sampling procedures

The compost was sampled immediately after it was removed from the window box. Samples were taken just below the surface layer in the center of the pile for maximum homogeneity (Kuter et al., 1985). They were kept in a mean temperature of 4° C prior to laboratory analyses.

4-2.3 Soil description

Soil was collected from the surface horizon of a Vance sandy loam (clayey kaolinitic, thermic Typic Kanhapludults) located in the Southern Piedmont Virginia. The soil sampled was air dried ground to pass a 4-mm sieve and stored at room temperature. Soil samples were analyzed (Table 3.2) by the Mehlich-1 (0.05 M HCl + 0.0125 M H₂SO₄) extractable method

Table 4-1. Elemental composition of organic amendments used in the mineralization study.

	C:N ratio	Moisture Content	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	
			-----%-----						-----ppm-----					
Poultry litter	6.6	36	3.45 [‡]	1.2	2.3	1.75	0.47	0.65	50	728	1223	528	459	
Yard waste compost	31.6	69	0.88	0.6	0.3	1.25	0.17	0.17	28	21	2908	335	97	
Poultry litter-yard waste compost														
	Initial C:N	Final C:N												
	15:1	8.4:1	56.6	1.53	2.5	1.33	1.72	0.41	-	36.5	502	2147	476	390
	20:1	10.8:1	53.2	0.97	2.5	1.02	1.47	0.33	-	27.7	350	1863	407	312
	25:1	9.6:1	50.5	1.3	1.4	0.71	1.09	0.22	-	26.3	202	1587	286	195

[‡] Base on dry weight

(Nelson et al., 1953) for P, K, Ca, Mg, Zn, and Mn; pH (1:1 soil/water ratio); and organic matter (Walkley and Black, 1934).

4-2.4 Laboratory incubation

Phosphorus mineralization was determined under laboratory conditions in aerobic incubators. The treatments were applied and mixed in duplicate to 100 g of the sieved soil. Treatments consisted of two rates of P (17.5 and 26.2 mg P kg⁻¹) applied as PYC from three different pre-digestion C:N ratios (15:1, 20:1, and 25:1). Poultry litter and YW were applied at a rate of 26.2 mg P kg⁻¹ of soil. Each treatment was thoroughly mixed in a separate plastic bag with the soil. The moisture content of soil and sand samples were determined gravimetrically and the samples in the plastic bags were watered as required with deionized water to percent field capacity (Table 4.1). The samples were incubated for 5, 14, 28, and 56 days at 25° C. At the end of each period of incubation, soils or sand sample were removed, immediately air dried, crushed, and stored for analysis purposes. In addition, a pure laboratory sand was used as an inert matrix. The sand sample was assumed not to have either organic matter or a microbial population. Treatments applied to the sand and incubation conditions for the treated sand were the same as for the aforementioned experiment with Vance soil. A microorganism's population was attained in the sand by injection of one g of the Vance soil to each sand culture. The data obtained from sand PYC mixtures should be indicative of the mineralization of the compost alone without P precipitation or adsorption reactions.

4-2.5 Soil P analysis

The amount of extractable P was determined in Mehlich-1 (0.05 M HCl and 0.0125 M H₂SO₄) method as described by Nelson et al. (1953). A 6.23g of soil sample was shaken for 5 minutes in 25 ml of Mehlich-1 solution on a reciprocating shaker at 180 oscillations min⁻¹, centrifuged, and filtered through Whatman no. 42 filter paper. The P concentrations in the soil extracts were colorimetrically determined by the molybdate blue ascorbic acid method

(Murphy and Riley, 1962) with a Hitachi model 100-20 spectrophotometer at 800 nm.

4-2.6 Statistics

All data were evaluated statistically by analyses of variance. Mean separations were performed by a LSD test using SAS program (Myers, 1992) where F-values were significant at the 0.05 probability level. Relationship between treatments, time of incubation versus mineralization were evaluated by linear and curvilinear regression analyses. The r-value of 0.95 herein is significant at the 0.05 probability level.

4-3 RESULTS AND DISCUSSION

The chemical composition of the organic amendments used in the mineralization study are shown on Table 4.1. Different patterns of P mineralization emerged during the 8 weeks of incubation (Fig. 4.1, 4.2, 4.3, and 4.4). The rates of P mineralization varied considerably with the type of organic amendment and length of incubation.

4-3.1 Soil incubation experiment

The potential P mineralized was the difference between the extractable P at time zero from extractable P after the incubation period (Fig. 4.1 and 4.3). The Vance soil amended with PL had the highest level of mineralized P after 56 days followed by the PYC from 15:1 and 25:1 C:N ratio of substrate at 26.2 mg P kg⁻¹ rate of application. There was difference in the amount of extractable P and the time of incubation ($P < 0.05$) indicating that the length of incubation was limiting the amount of P mineralization. With PL application, there was an early decrease of P produced until 14 days of incubation. This relationship indicates that a rapid immobilization occurred after PL application. The amount of P produced was about 9.9 mg P kg⁻¹ at 5 days and 8.2 mg P kg⁻¹ at 14 days. These levels of extractable P decreased to levels below those found at

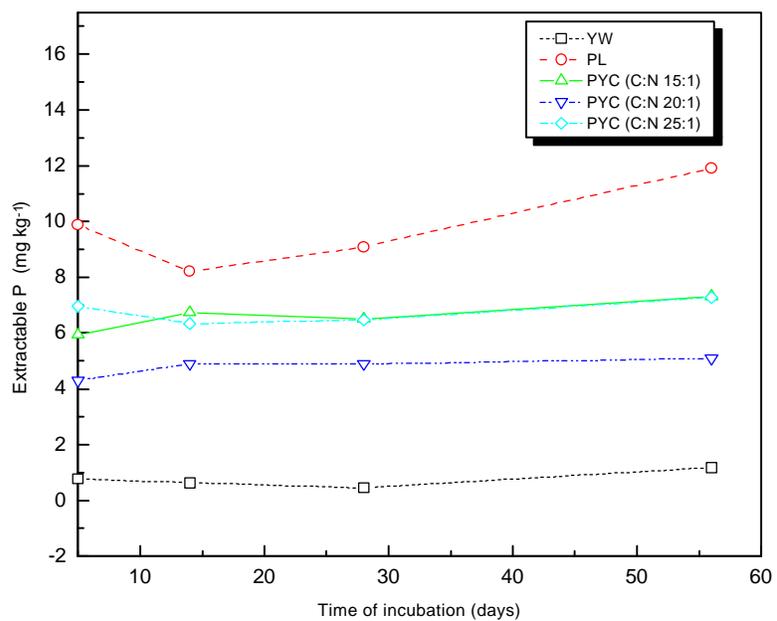


Fig. 4-1. Extractable P at 26.2 mg P kg⁻¹ rate of application in relation with the time of incubation on Vance soil.

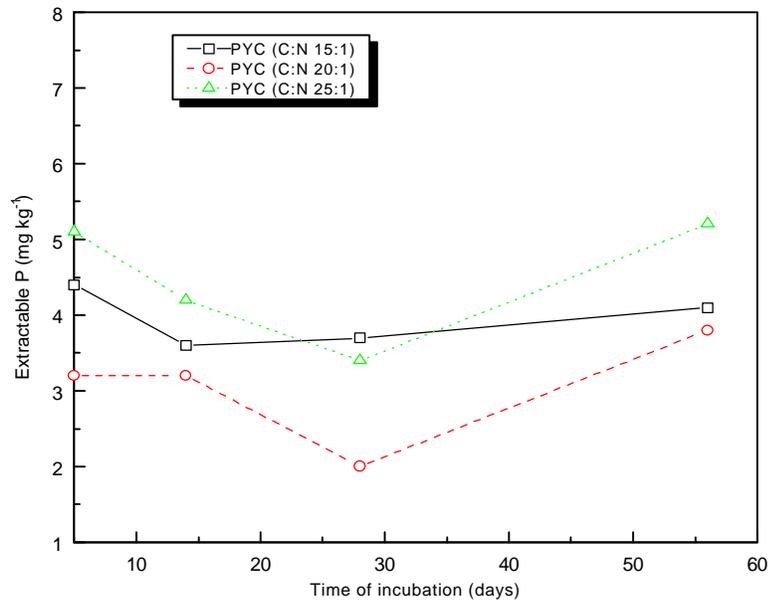


Fig. 4-3. Extractable P at 17.5 mg P kg⁻¹ rate of application in relation to the time of incubation on Vance soil.

time zero (Appendix Table 4.1). This relationship may be explained by incorporation of inorganic P consumption into microbial biomass (Sparrow et al., 1990) or by rapid sorption of inorganic P on soil by Fe and Al oxides (Muburi and Karathanasis, 1994; Hsu, 1964). These findings agree with those of Mozaffari and Sims (1996); Peperzak et al. (1959); and Bitzer and Sims (1988) who found that large amount of P in PL as inorganic P that can react with soil components.

Sharpley and Smith (1989) and Dalal (1977) indicated that with a C:P ratio $\leq 200:1$ P mineralization occurs and with a C:P ratio $\geq 300:1$ P immobilization occurs. The C:P of the PL in this study was approximately 28:1. As consequence, mineralization of organic P were expected to occur in soil amended with PL.

Phosphorus mineralization results in this experiment at the application rate $26.2 \text{ mg P kg}^{-1}$ (Fig. 4.1) with YW, PL and PYC are consistent with other incubation studies with cattle and poultry wastes. As an example, application of manure at a rate of 178 mg P kg^{-1} increased Mehlich-1 extractable P to about 214 mg P kg^{-1} at the end of 30 days incubation (Reddy, 1980a; Chang et al., 1991). At 28 and 56 days of incubation, a subsequent increase in extractable P was observed indicating that mineralization occurred after 14 days of incubation. The pattern of mineralization was similar for PYC from 25:1 C:N ratio substrate applied at a rate of $26.2 \text{ mg P kg}^{-1}$, i.e., rapid P immobilization started after 5 days of incubation followed by mineralization. The P mineralization observed on PYC 25:1 C:N ratio substrate was a slow release process as compared with PL (Fig. 4.1). For the soil amended with PL, $12 \text{ mg mineralized P kg}^{-1}$ soil constituted 45.4 % of total P, while in plot amended with PYC at 25:1 C:N ratio substrate, $7.3 \text{ mg mineralized P kg}^{-1}$ constituted 28% of total P.

The P extractable from soil amended with PYC from 15:1 and 20:1 C:N ratio of substrate showed a sustained mineralization trend throughout the 56 days of incubation (Fig. 4.1). There was an increase in extractable P until 14 days, followed by a plateau. Values of extractable P ranged from 5.9 to 7.3 mg P kg^{-1} and 4.3 to 5.1 mg P kg^{-1} for PYC from 15:1, and 20:1 ratio substrates, respectively. The slow mineralization rate as compared with PL may reflect a low level of readily mineralizable P.

The pattern of extractable P release with YW application varies slightly with the period of incubation (Fig. 4.1). The low mineralization rate (about 4.5%) for YW as compared with PL and PYC may have been due to a relatively high C:P ratio and low readily mineralizable P in the YW. Little decrease in rate of P mineralization was observed between 5 and 14 days which may have resulted from lower P adsorption from both the initial P in the YW and P mineralized from the YW during the first phase of incubation. Overall the extractable P was curvilinearly related to the time of incubation, the r-values were 0.78, 0.82, and 0.93 for the PYC from the 15:1, 20:1 and 25:1 C:N ratio substrates. The curvilinear relationship indicates that the P release increased as the readily available organic material was degraded.

The pattern of extractable P release with PYC at the application rate of 17.5 mg P kg⁻¹ differs slightly from the pattern of 26.2 mg P kg⁻¹ application rate. A decrease of P produced was observed until 28 days of incubation with PYC at 20:1 and 25:1 C:N ratio substrates (Fig. 4.3). With PYC application of 15:1 C:N ratio, there was a decrease in extractable P until 14 days followed by a plateau. This relationship indicates that immobilization occurred after application of PYC.

The extractable P from soil amended with PYC at 25:1 C:N ratio substrate at the application rate of 17.5 mg P kg⁻¹ had the highest level of P mineralization after 56 days of incubation followed the PYC from the 15:1 and 20:1 C:N ratios. There were differences in the extractable P release with the time of incubation ($P < 0.05$). Extractable P values ranged from 3.6 to 4.4 mg P, 2 to 3.8 mg P and 3.4 to 5.2 mg P kg⁻¹ for PYC from 15:1, 20:1, and 25:1 ratio substrates, respectively. The low mineralization rate may have been due to low readily mineralizable P in the PYC at the application rate of 17.5 mg P kg⁻¹.

4-3.2 Sand incubation experiment

The P mineralization from organic amendment may be biased downward by adsorption of mineralized P by soil components. The mineralized P could be sorbed by clay minerals and hydrous oxides of Al and Fe in the Vance soil. Therefore, it is important to determine P

mineralization rates in sand cultures, i.e, in the absence of soil components that sorb P.

Sand amended with PL had the highest level of mineralized P after 8 weeks of incubation period. The PYC from 25:1 C:N ratio had the second highest rate of P mineralization (Fig. 4.2). Poultry litter had relatively fast initial rates of P release that increased rapidly after 28 days of incubation. The P mineralization of PL ranged from 41.2 to 58.0 % in 14 days. At the same application rate with PYC, the mineralization rate ranged from 20.4 to 50.2 % at 14 days of incubation. Among the organic amendments, PL had the highest release of P during the 56 days of incubation. The differences observed in P mineralization rate with PL could be attributed to a high content of readily mineralizable P forms in the PL.

During the 56 day incubation period, negligible P was released on YW-sand cultures (Fig. 4.2). The lowest P mineralization rate occurred with YW and ranged from 1.2 to 4.3 %. A similar finding with YW-Vance soil culture was attributed to the relative high C:P ratio and low amount of readily mineralizable P compounds in YW. Overall, the relatively slow mineralization of P from PYC can be attributed to the high amount of C that may result in immobilization mineralized P (Birch, 1961). Poultry litter component did contribute dramatically more to P release than YW materials.

The trend of P release was similar for all PYC applied at the rate of 26.2 mg P kg⁻¹ (Fig. 4.1). However, the mineralization rate was about half of the observed rate for PL and ranged from 35.7 to 42.2%, 20.1 to 37.1 %, and 38.8 to 51.6% for PYC from 15:1, 20:1, and 25:1 C:N ratio substrates, respectively. The first 28 days, large amounts of extractable P were produced before the level began to decrease. The decrease in P levels with time may be the result of immobilization. Taylor et al. (1978) found that both mineralization and immobilization of the organic P occur simultaneously with the application of organic waste.

Extractable P also declined with time as a result of chemical fixation. In acid soils P is adsorbed and released hydrous oxides of Fe and Al (Taylor, 1978). The P that is released into soil solution can undergo immobilization as P is incorporated into microbial cells.

The pattern of extractable P release with PYC at the application rate of 17.5 mg P kg⁻¹

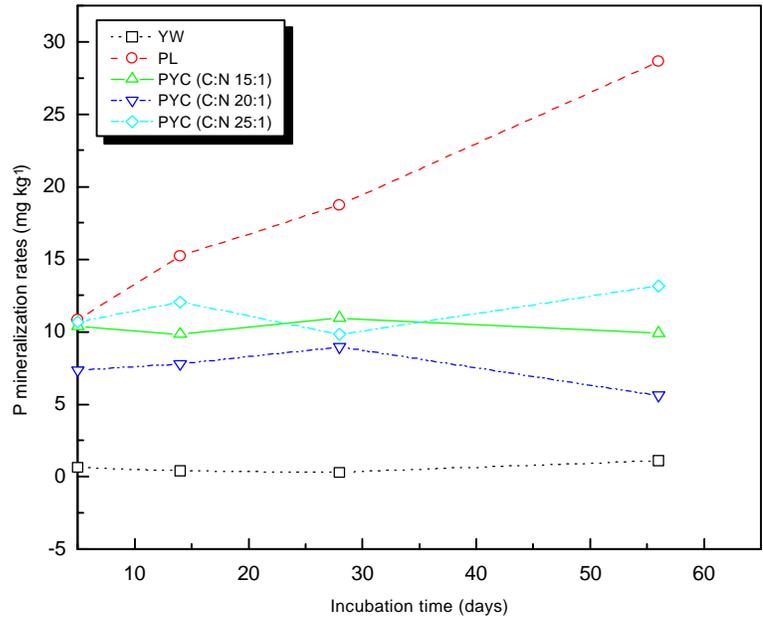


Fig. 4-2. Extractable P at 26.2 mg P kg⁻¹ application rate in relation to the time of incubation on sand.

differs slightly with the pattern of $26.2 \text{ mg P kg}^{-1}$ application rate. Among the PYC amendments, the PYC from pre-composted 15:1 C:N ratio had the highest release of P during the 56 days of incubation. The pattern of P release was similar from PYC for 15:1 and 25:1 C:N ratios, i.e., fast initial rates of P release that decreased slightly after 14 days of incubation (Fig 4.4). The PYC from the 20:1 C:N ratio substrate had a decrease in P release after 28 days of incubation. The correlation between P release and the length of incubation suggests that the PYC contains large amounts of degradable materials and that, during decomposition, P will be released through mineralization.

4-4 CONCLUSION

This laboratory study was conducted at optimum soil moisture and temperature conditions for mineralization. Although the results may not quantitatively reflect a field situation some conclusions can be made. Incubation of PL and PYC applied in Vance soil for 56 days showed that substantial P mineralization occurred and was that the rate of mineralization consistently greater for PL. Relatively slow mineralization for PYC was attributed to the high C:P ratio that may have resulted in immobilization of mineralized P. The high rate of mineralized P from PL as compared with PYC suggests that PL contained large amounts of P which could be released quickly after application. In contrast, high rates of mineralization were observed under PL for PYC application in quartz sand at the end of 56 days incubation. It was concluded that quartz sand provided a more reliable P mineralization rate because it did not contain components that fix P.

Phosphorus mineralization and immobilization may have occurred simultaneously in soil even though the processes are independent of each other. These amounts released could meet the P uptake requirements for crop yields. However, under improper management, loss of P in runoff may occur from land receiving frequent application of PL which may lead to eutrophication.

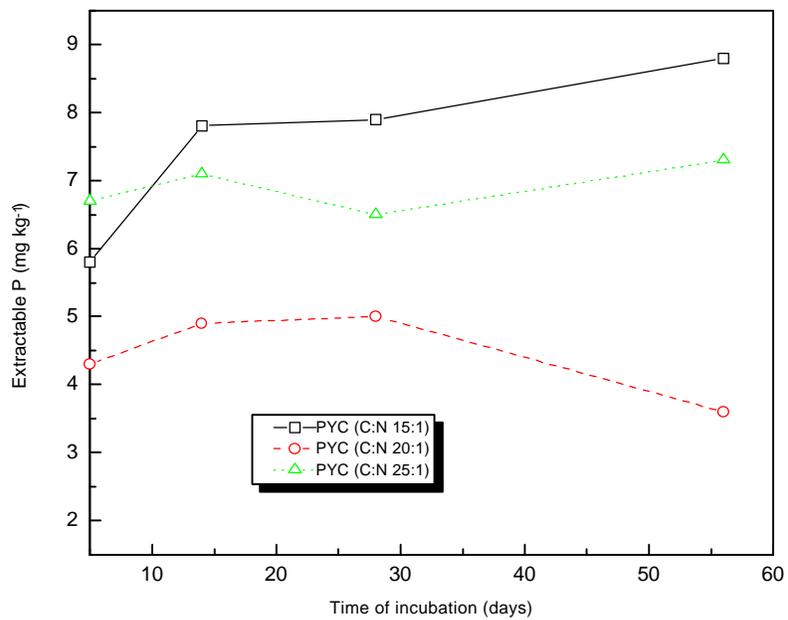


Fig. 4-4. Extractable P at 17.5 mg P kg⁻¹ application rate in relation to the time of incubation on sand.

Conversely, application PYC with lower P mineralization rates may reduce the groundwater pollution.

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