Phosphorus mineralization of bioslurry and other manures in soil

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The experiment was conducted to see the phosphorus (P) mineralization pattern of bioslurry under aerobic and anaerobic soil conditions. Two bioslurry (cowdung bioslurry and poultry manure bioslurry) and their original manure (cowdung and poultry manure) at 3, 5, 10 and 20 t ha-1, respectively were thoroughly mixed with soil and incubated in aerobic and anaerobic moisture condition for 12 weeks. Among the four different types of manure, P release from poultry manure slurry was the highest. Poultry manure and cowdung slurry recorded very closer amount of available P. Both cowdung slurry and poultry manure slurry released higher amount of P compared to their original state (cowdung and poultry manure). P mineralization reaches in peak within 4-6 weeks of incubation. Under anaerobic condition the P mineralization was found higher compared to aerobic condition. The P mineralization data fitted strongly to the first order kinetic model. The bioslurries had lower rate of mineralization but had higher potentiality to release P in the soil compared to their original state.

Key words: Bioslurry, cowdung, incubation, phosphorus mineralization, poultry manure

INTRODUCTION

Phosphorus (P) is the second important key plant nutrient after nitrogen (N) which strongly affects the overall growth of plants by influencing the key metabolic processes such as cell division and development, energy transport (ATP, ADP), signal transduction, macromolecular biosynthesis, photosynthesis and respiration of plants (Shenoy and Kalagudi, 2005; Khan and Sharif, 2012, Khan et al., 2009, 2014). Phosphorus is added to the soils as soluble P fertilizers, a part of which (1 %) is utilized by plants and the rest is rapidly converted into insoluble complexes (Mehta et al., 2014) by entering into the immobile pools through precipitation reaction with highly reactive Al3+ and Fe3+ in acidic, and Ca2+ in calcareous soils (Khan et al., 2009). These metal ion complexes precipitated about 80 % of added P fertilizer hence, the recovery efficiency of P throughout the world is not more than 20 % of applied P (Qureshi et al., 2012). Considering the low recovery of applied and native P and high cost of chemical phosphatic fertilizers besides increasing concern of environmental degradation (Aziz et al., 2006; Khan et al., 2014), it has become imperative to find viable solutions to tackle the problem. In this regard, two management options can be workout simultaneously for efficient utilization of P fertilizers i.e. (i) to increase the recovery and solubility of applied P fertilizers and (ii) to replace the expensive chemical P fertilizers by novel, cheaper, more ecological but nevertheless efficient P sources, such as use of organic manures in our agriculture inputs system.

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Unbalanced use of chemical fertilizers has an adverse effect on soil. To achieve improved and sustainable soil fertility and crop yield, judicious use of chemical fertilizers coupled with organic manure is essential (FRG 2012). Organic manure in Bangladesh includes cowdung, poultry manure, compost and green manure. Karim et al. (2010) reported that there are 22.9 million cattle and 262.62 million poultry birds in Bangladesh which produce manure at 68700 and 10505 mt day⁻¹, respectively with effort of both GO and NGOs. Recently in this country, biogas technology has been introduced to meet the energy crisis. Cowdung and poultry manure are commonly used in biogas plant. After extraction of biogas (50-70% CH₄, 30-40% CO₂), bio-slurry comes out of the digester as an anaerobically decomposed manure (Mosquera et al., 2000). Nutrient mineralization potential and decomposition patterns of organic residues are variable depending on the chemical composition (Mtambanengwe and Kirchmann, 1995). During decomposition, organic material changes in both its physical and chemical structure. Easily decomposable part of soil organic matter undergoes quick mineralization and becomes a part of soil humus, a small portion of which may remain in soil for thousands of years (Reddy et al., 2002).

There are some differences in the mineralization of organic manure under aerobic and anaerobic conditions. The most striking difference between anaerobic and aerobic decompositions lies in the nature of end products. In normal, well drained soils, the main end products are CO₂, water, nitrate, sulphate and resistant humus; in submerged soils they are CO₂, water, H₂, CH₄, NH₃, mercaptans, H₂S and partially humified residues. Despite recent literature provides valuable information on many aspects of phosphorus (P) mineralization, the interaction between the kind of organic manures and P mineralization under aerobic and anaerobic conditions is not well understood. The present paper comparatively discusses the P mineralization pattern in the bio-slurry and other manure amended soils under aerobic and anaerobic conditions.

**MATERIALS AND METHODS**

The incubation experiment was conducted in the laboratory of the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh. Bangladesh Agricultural University (BAU) located 24.75° N latitude and 90.5° E longitude with an elevation of 18 m from the sea level. The experimental location is characterized by sub-tropical humid weather conditions. The mean annual rainfall of the experimental area during 2011-2012 was around 2500 mm and five months from May through September receives more than 2000 mm rainfall. March is the peak evaporation month, soil moisture stress continues from December through April. The monthly 208 mm average rainfall, 20.1°C minimum temperature, 29.5°C maximum temperature and 73.2% relative humidity were recorded at BAU during study period. The BAU soil belongs to ‘Sonatala’ soil series an Inceptisol (Brammer 1980; FAO 1988) under the AEZ 9 (Old Brahmaputra Floodplain) and characterized by Non-Calcareous Dark Grey Floodplain Soil.

Soils were collected from the BAU farm, Mymensingh at 0-15 cm depth of a field and were thoroughly mixed. The soil sample was brought to the laboratory and spread on brown paper for air-drying. The air-dry soils were ground and passed through a 2-mm sieve to remove roots and other debris. The soil was silt loam, with 1.14 % O.C., 6.5 pH, 1.17 % N, 6.0 mg kg⁻¹ NaHCO₃ extractable P, 0.12 cmol kg⁻¹ NH₄OAc extractable K, and 14.0 mg kg⁻¹ CaCl₂-extractable S. The elements were determined by some standard methods, as outlined by Page et al., (1982). Four types of organic manure viz. cowdung, cowdung slurry, poultry manure and poultry manure slurry were used in this study. The manures were air-dried, ground and passed through a 2-mm sieve. The chemical composition of various manures is presented in Table 1.

An amount of 100g air-dry soil was weighed into a series of small plastic containers. Air dry finely ground cowdung, cowdung slurry, poultry manure and poultry manure slurry at 1.5, 2.5, 5.0 and 10.0 g kg⁻¹ (equivalent to 3, 5, 10 and 20 t ha⁻¹, respectively) were thoroughly mixed with soil in separate containers. A control container (without organic manure) was run along with each set of incubation. Two moisture levels – one field capacity/aerobic (25% soil moisture) and another submerged/anaerobic condition (1 cm standing water above soil) were maintained. The containers were incubated at room temperature (25 ± 2°C) for 12 weeks.

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**Table 1. Chemical composition of different manures**

<table>
<thead>
<tr>
<th>Manure</th>
<th>C (%)</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>S (%)</th>
<th>C:N</th>
<th>C:P</th>
<th>C:K</th>
<th>C:S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cowdung (CD)</td>
<td>38.6</td>
<td>1.70</td>
<td>0.88</td>
<td>2.02</td>
<td>0.41</td>
<td>22.8</td>
<td>43.8</td>
<td>19.1</td>
<td>95.3</td>
</tr>
<tr>
<td>CD slurry</td>
<td>29.3</td>
<td>1.84</td>
<td>1.30</td>
<td>0.93</td>
<td>0.42</td>
<td>16.0</td>
<td>22.6</td>
<td>31.6</td>
<td>69.4</td>
</tr>
<tr>
<td>Poultry manure</td>
<td>34.9</td>
<td>2.28</td>
<td>1.48</td>
<td>2.23</td>
<td>0.53</td>
<td>15.3</td>
<td>23.5</td>
<td>15.6</td>
<td>65.7</td>
</tr>
<tr>
<td>PM slurry</td>
<td>19.2</td>
<td>1.70</td>
<td>2.52</td>
<td>0.67</td>
<td>0.67</td>
<td>11.3</td>
<td>7.6</td>
<td>28.5</td>
<td>28.5</td>
</tr>
</tbody>
</table>
Phosphorus mineralization was varied by the types and rates of manure, soil moisture content and incubation time (Figure 1). Among the manures, P release from poultry manure slurry was the highest. Poultry manure and cowdung slurry recorded very closer amount of available P. Among the four different types of manure, cowdung recorded the lowest amount of available P (Figure 1). Figure 1 further confirms that cowdung slurry and poultry manure slurry released higher amount of P compared to their original state (c Arcus and poultry manure).

Comparing the effects of manure rates, the 3 t ha\(^{-1}\) recorded the lowest amount of P mineralization and it progressively increased with increasing rates of manure application and accordingly the highest P mineralization was noted with the highest rate of manure application (20 t ha\(^{-1}\)). There was a remarkable variation in P mineralization between aerobic and anaerobic soil conditions. Under anaerobic condition the P mineralization was found higher compared to aerobic condition (Figure 1). The maximum P mineralization of 9.1, 11.9, 26.3 and 40.4 mg kg\(^{-1}\) at 3, 5, 10 and 20 t ha\(^{-1}\) manure rates, respectively was recorded under aerobic soil condition; these values in anaerobic condition were 12.1, 18.4, 27.1 and 44.9 mg kg\(^{-1}\), respectively. Such result reveals that anaerobic condition is favorable for P mineralization than aerobic condition. The reason can be attributed to the attainment of neutral soil pH during submergence which condition favored P availability in soils.

A distinct variation in P mineralization was observed across the incubation times. Phosphorus mineralization progressively increased with passage of time and reached its peak within 4\(^{th}\) to 6\(^{th}\) week of incubation and thereafter it gradually decreased until expiry of incubation time (Figure 1). Naher et al. (2004) reported that the P mineralization of fresh poultry manure, partially decomposed cowdung and rice straw took place after 15 days of application and with the passing of time it increased steadily. They found higher P mineralization in the cowdung and poultry manure treated soils. Abbasi et al. (2015) reported that integrated use of phosphate solubilizing bacteria (PSB) and poultry manure (PM) with rock phosphate (RP) treatment stimulated P mineralization by releasing a maximum of 25 mg P kg\(^{-1}\) that was maintained at high levels without any loss. These results suggest that use of PSB and PM with insoluble RP or with soluble P fertilizers (SPF) could be a promising management strategy and viable technology to utilize both PM or low-grade RP and SPF efficiently for crop production and nutrient improvement in the cropping systems.

The net P mineralization data were fitted to different kinetic functions. The best fit was using a first-order kinetic model \[ P_{\text{min}} = P_0 \left(1-e^{-kt}\right), \] being \(P_{\text{min}}\) the phosphorus mineralized from soil in a given time, \(P_0\) the potentially mineralizable pool of P, \(k\) the mineralization rate constant, and \(t\) the time. The parameter values and coefficients of determination for the P mineralization kinetics are presented in Table 2. The P mineralization data fitted strongly in the first order kinetic model, the r value being found from 0.7001 to 0.8117 across the manure types and manure application rates. Across the manure types and rates the \(P_0\) value (mineralization potential) was always higher in anaerobic condition compared to respective aerobic condition, which indicates the higher scope of P mineralization under anaerobic soil system. Among the manures, the highest of 10.65, 12.93, 20.92 and 39.23 mg kg\(^{-1}\) \(P_0\) was recorded by poultry manure slurry at 3, 5, 10 and 20 t ha\(^{-1}\) rates, respectively under anaerobic condition. In this moisture condition second, third and forth position was ranked by poultry manure, cowdung slurry and cowdung, respectively across the manure rates. Regarding aerobic condition, considering \(P_0\) value poultry manure slurry further ranked the first position in all the manure rates. Poultry manure ranked second position in 3 and 20 t ha\(^{-1}\) rates, cowdung slurry being second in 5 and 10 t ha\(^{-1}\) rates. In most of the cases, slurry whether cowdung and poultry manure had the higher mineralization potential compared to their original state. The overall results indicate that poultry manure source is able to supply more P compared to cowdung source in relation to mineralization potential values.

The mineralization rate constant (k value) of first order kinetic model was found higher in cowdung source.
Phosphorus mineralization of bioslurry and other manures in soil

Aerobic condition

![Aerobic Condition Graphs]

Anaerobic condition

![Anaerobic Condition Graphs]

Figure 1. Trend of net P mineralization from manures under aerobic and anaerobic conditions

CD- Cowdung, CD sl- Cowdung slurry, PM-Poultry manure, PM sl-Poultry manure slurry

compared to poultry manure source across the soil moisture conditions (Table 2). It indicates that cowdung source mineralize faster and require less time to mineralization than the poultry manure source. When slurries and their original state were considered it found that maximum cases slurries had the lower k value than their original state. The results clearly indicate that slurries had lower rate of mineralization but had potentiality to supply higher P to the soil compared to their original state.
CONCLUSION

Poultry manure source was found as a better source of P for plant in soil. Both poultry manure slurry and cowdung slurry have ability to supply P steadily, thus plant may uptake it for long time compared to their original state (poultry manure and cowdung).

ACKNOWLEDGEMENT

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REFERENCES


Table 2. Parameter values and coefficients of determination for the P mineralization kinetics of different manures

<table>
<thead>
<tr>
<th>Rates of manure</th>
<th>Types of manure</th>
<th>Aerobic condition</th>
<th></th>
<th>An aerobic condition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3 t ha⁻¹</td>
<td>Cowdung</td>
<td>P₀</td>
<td>2.749</td>
<td>0.1350</td>
<td>7.601</td>
</tr>
<tr>
<td></td>
<td>Cowdung slurry</td>
<td>k</td>
<td>0.7001</td>
<td>0.1048</td>
<td>0.715</td>
</tr>
<tr>
<td></td>
<td>Poultry manure</td>
<td>r adj*</td>
<td>2.0073</td>
<td>0.1201</td>
<td>0.767</td>
</tr>
<tr>
<td></td>
<td>Poultry manure slurry</td>
<td>F</td>
<td>6.995</td>
<td>0.0991</td>
<td>0.8117</td>
</tr>
<tr>
<td>5 t ha⁻¹</td>
<td>Cowdung</td>
<td>P₀</td>
<td>4.482</td>
<td>0.2027</td>
<td>0.7690</td>
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<tr>
<td></td>
<td>Cowdung slurry</td>
<td>k</td>
<td>7.601</td>
<td>0.1048</td>
<td>0.715</td>
</tr>
<tr>
<td></td>
<td>Poultry manure</td>
<td>r adj*</td>
<td>2.0073</td>
<td>0.1201</td>
<td>0.767</td>
</tr>
<tr>
<td></td>
<td>Poultry manure slurry</td>
<td>F</td>
<td>9.274</td>
<td>0.1097</td>
<td>0.7370</td>
</tr>
<tr>
<td>10 t ha⁻¹</td>
<td>Cowdung</td>
<td>P₀</td>
<td>8.774</td>
<td>0.2135</td>
<td>0.7624</td>
</tr>
<tr>
<td></td>
<td>Cowdung slurry</td>
<td>k</td>
<td>7.601</td>
<td>0.1048</td>
<td>0.715</td>
</tr>
<tr>
<td></td>
<td>Poultry manure</td>
<td>r adj*</td>
<td>2.0073</td>
<td>0.1201</td>
<td>0.767</td>
</tr>
<tr>
<td></td>
<td>Poultry manure slurry</td>
<td>F</td>
<td>18.79</td>
<td>0.2047</td>
<td>0.7671</td>
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<tr>
<td>20 t ha⁻¹</td>
<td>Cowdung</td>
<td>P₀</td>
<td>16.08</td>
<td>0.1782</td>
<td>0.7379</td>
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<tr>
<td></td>
<td>Cowdung slurry</td>
<td>k</td>
<td>7.601</td>
<td>0.1048</td>
<td>0.715</td>
</tr>
<tr>
<td></td>
<td>Poultry manure</td>
<td>r adj*</td>
<td>2.0073</td>
<td>0.1201</td>
<td>0.767</td>
</tr>
<tr>
<td></td>
<td>Poultry manure slurry</td>
<td>F</td>
<td>25.48</td>
<td>0.1303</td>
<td>0.7972</td>
</tr>
</tbody>
</table>

Here, P₀: potentially mineralizable pool of P, k: mineralization constant rate, r: correlation coefficient F: F value of ANOVA table, P: probability level

" r value: 0.0 to 0.2: very weakly fit, 0.2 to 0.4: weakly fit, 0.4 to 0.7: moderately fit, 0.7 to 0.9: strongly fit, 0.9 to 1.0: very strongly fit "


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