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Phosphorus mineralization in an alluvial soil as influenced by organic manure addition and time of incubation

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Abstract
Transport of phosphorus (P) from agriculture often causes eutrophication of surface water systems, which is particularly a concern in alluvial soil regions because of coarse texture and intermediate water and cation exchange capacity. Organic residues are increasingly being applied to soil because of their ability to increase soil organic carbon that also improves soil physical, chemical and biological properties. However organic manures contain variable amounts of phosphours, which upon mineralization gets released, and is of environmental concern. To evaluate the risk of P losses, an experiment was carried out in an alluvial soil with three manures viz., farm yard manure (FYM), oil cake and pig manure, incubated at the rate of 4, 40, 80 t ha^{-1} for a period of 2, 72, 168, 336, 480, 1440, 2160 hours at constant temperature and moisture and net phosphorus mineralized was evaluated. It was found that the three manures differed widely in their C, N and P content and C/N and C/P ratios and consequently the mineralization pattern differed. FYM had higher C/P ratio as compared to oil cake and pig manure; consequently the net P mineralized in pig manure was the highest at all rates of P addition followed by oil cake and FYM throughout the time intervals studied. It was concluded the there was greater risk of P losses from high doses of pig manure addition in alluvial soils as compared to oil cake and FYM. Hence it was suggested that manures with different C/P ratios could be mixed to maintain a reasonably high P supplying capacity in soil at the same time the risk of P losses could be avoided.

Keywords: Organic manure, P mineralization, incubation, environmental risk.

Introduction
Phosphorus (P) is one of the major nutrients limiting crop production. The mobility of P in soil is low compared with other nutrients due to high capacity of soil material to adsorb P. When P in water or soluble phosphatic fertilizers is added to soils, some of it is immobilized or forms compounds that have low solubility either by adsorption or precipitation, or both. Therefore, not all the P applied is available to plants. The degree of P sorption is affected by environmental factors, soil components and properties as well as the amount of P added. In calcareous soils, precipitation of calcium phosphate is supposed to be a major factor in the time loss of P availability (Freeman and Rowell 1981) [2].

In recent years, the application of organic residues with high organic matter content, such as animal manures, compost, crop residues and other urban and industrial wastes to semi-arid soils, has become a common environmental practice for maintaining soil organic matter and supplying plant nutrients (Tejada *et al.* 2006) [3]. Organic residues have been frequently suggested to supplement chemical fertilizers in soil fertility management (Damodar Reddy *et al.* 2001) [4]. Phosphorus in plant residues is a potential P source in plant production systems and the combined use of chemical fertilizers with organic manures or crop residue in an appropriate ratio can result in increased nutrient availability and crop yields (Kumar *et al.* 1999) [5]. The quality of organic materials and their ability to release P should be known and accounted for in planning of the needed supplemental quantities of fertilizer P and their timing (Hadas *et al.* 2004) [6]. The release of P from manure is dependant on its pattern of mineralization, which among other factors is governed by its C/P ratio. There is little information on the time dependant release of P from organic manures. The present study was aimed at evaluating P release from three organic manures differing in their C and P contents.

Materials and Methods

An incubation experiment was conducted with three organic manures namely, FYM, oilcake and pig manure. The FYM was obtained from the Department of Animal Husbandry and Dairying, of the Institute of Agricultural Sciences, BHU, Varanasi; oilcake was obtained from the oil mill located at Lalpur, Mirzamurad, Varanasi and pig manure were collected from State Government Piggery farm, Shahanshahpur, Varanasi. The organic manures were dried at room temperature and ground to pass through 2 mm sieve. Air dried ground (less than 2 mm) samples of organic manures were analysed for total C, H and N by a CHN analyzer (Thermo Finnigan). Sample were digested in diacid (nitric acid and perchloric acid) and the total P in the digest was measured by the ammonium molybdate-vanadate yellow colour method. The C/N and C/P ratios were calculated from total C, total N and total P data. The pH was measured was measured by a glass electrode pH meter using distilled water in the ration 1:5.

The soil used in the experiment was an alluvial soil, which was obtained from Agricultural Research Farm of the Institute of Agricultural Sciences, BHU, Varanasi. Bulk soil samples from 0-15 cm depth were collected and the soil was air-dried and passed through a 2 mm sieve before analysis. The pH of soil was measured in 1:2.5 (soil: water suspension) after equilibrating for 30 minutes, with the help of glass electrode digital electrode pH meter. Soil suspension was allowed to settle till supernatant become clear. Electrical conductivity was measured with the help of EC meter and expressed as dS m^{-1} (Sparks, 1996). CEC of soil was determined by sodium saturation method using sodium acetate (NaOAC pH 8.2). Particle size analyses was done using a hydrometer as described by Bouyoucous (1927). The water holding capacity of the soils were measured using Keen- Rackzowski box (Black, 1965). Organic carbon in soil was estimated by chromic acid wet digestion, followed by titrimetric measurement of unreacted dichromate (Walkley and Black, 1934). The calcium carbonate (%) of soil was determined using rapid titration method given by Puri (1930). Available nitrogen content of soil was determined by alkaline permanganate method (Subbia and Asija, 1956), available phosphorus content by Olsen's method (Olsen, 1954) and available potassium content by extraction using 1 **N** ammonium acetate and analysed by flame photometer (Hanway and Heidal, 1952). Exchangeable Ca and Mg was extracted in 1 **N** ammonium acetate and measured by EDTA titration (Hesse, 1970). Total organic carbon content was determined by using the method of Yeoman and Bremmer (1988) [13], total phosphorus by digesting the soil in nitric-perchloric acid mixture and determining the colour developed. The fractions of P fractionation were measured as outlined in Page *et al.* (1982) [12].

The incubation study was carried out in plastic pots wherein 1 kg soil was thoroughly mixed with organic manure @ 0, 4, 40 and 80 t ha^{-1} equivalent to 0, 2, 20, and 40 g kg^{-1} on dry weight basis and incubated for 2, 72, 168, 336, 480, 1440, and 2160 hours at 25°C. Appropriate amount of water was added to bring the soil to the estimated field capacity and the samples were kept moist by adding distilled water as needed. After the specified time intervals, samples were taken and air dried before analysis and sub-samples were analyzed for Olsen- P (Olsen and Sommers 1982) [12]. All incubation experiments were carried out in triplicate.

Results and Discussion

Characteristics of Soil and Organic manures

The soil used in the study was alluvial soil and salient soil properties are present in Table 1. The soil was brown in colour and contained 30.60% clay and was low in cation exchange capacity (8.76 C mol (p+) Kg^{-1}). The water holding capacity was (42.65%) and pH was neutral (7.5) and had low salt content (0.02 dS m^{-1}). The soil had little calcium carbonate (0.28%) and organic carbon was low (4.21g kg^{-1}). The available nitrogen content was low (163 kg ha^{-1}); available phosphorus content was medium (18.80 kg ha^{-1}), available potassium content was 244 kg ha^{-1} and exchangeable calcium and magnesium content was 7.0 and 7.5 cmol (p^+) kg^{-1} soil respectively.

Organic manures used in the study were FYM, pig manure, and oilcake and their chemical composition is presented in Table 2. All the manures had an acidic pH (5.6 -6.8 units). The manures varied in their carbon and hydrogen content from 23.88 to 40.31% and 3.44 - 5.78% with oilcake showing higher C and H content. The total N content also varied widely from 1.73 to 6.43% with lowest N content in pig manure and higher in oilcake; FYM and pig manure had similar N contents. Total P content varied widely between 0.38 and 1.27%, pig manure had the higher P content (1.27%), as compared to oilcake (0.96%) or FYM (0.38%). The C/N ratio varied from 6.2 to 14.8; narrow C/N ratio was found in oilcake and wide ratio in FYM, whereas pig manure had intermediate C/N ratio. Wide variation in C/P ratio was also noted. FYM had a wide C/P ratio (69.4), oilcake had an intermediate ratio (41.9) while pig manure had low C/P ratio (18.8).

Mineralization of P from organic manure

Mineralization study was carried out by incubating soil with either 4, 40 or 80 t ha-1 and the incubation was carried out for 2160 hours; a control was maintained to compare the effect of manure incubation. At the end of the incubation period, soils were extracted for P and estimated by the method of Murphy and Riley (1962) [8]. It was found that the net P mineralized increased with increasing time interval but did not attain a study value within the time period of incubation (Table 3); but the rate of P mineralization decreased with increase in the time period of incubation. The net P mineralized increased from 0.3 mg kg^{-1} to 2.0 mg kg^{-1} in case of 4 t ha^{-1} application of FYM, whereas the increase was 0.8 to 3.3 mg kg^{-1} on application of 40 t ha^{-1} and 1.5 to 7.3 mg kg^{-1} in case of 80 t ha^{-1}. The increase in P mineralization was 5.7 times, 3.1 times and 3.9 times between 2 and 2160 hrs of incubation for 4, 40 and 80 t ha^{-1} application rate respectively (Fig 1-3). Garg and Bahl (2008) [7] suggested that organic manures enhance the phosphatase activity in soil which in turn provides more P in soil solution through mineralization/solubilization.

Similarly the net P mineralized increased from 1.5 mg kg-1 to 3.7 mg kg^{-1} ; 3.6 to 5.8 mg kg^{-1} and 4.8 to 8.3 mg kg^{-1} on application of 4, 40 and 80 t ha^{-1} of oilcake. This increase was 1.5, 0.61 and 0.73 times for 4, 40 and 80 t ha^{-1}. Although the C/P ratio of FYM and oilcake was in the medium range, oilcake had a higher total P content (0.96% P) than FYM (69.4). This is probably the reason why the net P mineralized in case of oilcake was more than that of FYM both at the beginning and end of incubation period. A comparison of Fig 1-3 reveals that mineralization was rapid during the initial period of mineralization and the curve flattened out after 336 hr of incubation in case of oilcake. But in case of FYM, the rate of mineralization appeared to increase at a steady state thought the period of incubation study.

P mineralization from pig manure is presented in Table 3 and the data reveals that the mineralization increased from 8.3 to 10.2 mg P kg^{-1} in case of 4 t ha^{-1} application rate (an increase of 0.23 times); whereas the increase was from 9.1 to 12.3 mg kg^{-1} in case of 40 t ha^{-1} (an increase of 0.35 times) and 9.3 to 12.9 mg kg^{-1} (an increase of 0.38 times). Perusal of Fig 1-3 reveals that mineralization was rapid in the initial stage of mineralization and decreased thereafter. Thus rapid increase in rate of mineralization in pig manure is probably because of low C/P ratio (18.8) and high P content (1.27% P).

Conclusion

Organic manure is generally applied to improve the organic carbon content and maintained physic-chemical and biological properties and fertility status of soil. Finding of the present study indicate that organic manures vary in their carbon, nitrogen and phosphorus content and therefore have varying mineralization potential. When FYM, oil cake and pig manure were incubated at three different rates in an alluvial soil, higher phosphorus availability was observed in pig manure followed by oil cake and poultry manure amended soil. Higher P availability in pig manure amended soil was due to higher mineralization potential of pig manure and oilcake as a consequence of higher P content and lower C/P ratio. Rapid transformation rate is not necessarily desirable because the mineralized P is not always subject to leaching losses in soil. However since concerns of nutrient leaching, leading to eutrophication and environmental pollution are on the rise, a combination of residues with different transformation rate patterns would be ideal for P supply in soil.

Table 1: Initial properties of soil under study

Properties	Value
pH	7.5
EC (dS/m)	0.12
CEC (cmol (p+) kg^{-1})	8.76
Texture (%)	
Sand	44.30
Silt	26.43
Clay	30.60
Water holding capacity (%)	42.65
Oxidisable Organic carbon (g kg^{-1})	7.85
Calcium carbonate (%)	0.28
Available (kg ha^{-1})	
N	163
P_2O_5	18.8
K_2O	244
Exchangeable (cmol (p+) kg^{-1})	
Ca	7.55
Mg	7.0
Total (%)	
C	0.38
P	0.04
P fractions (ppm)	
Soluble P	0.67
Al bound P	14.17
Fe bound P	13.00
Reductant soluble P	4.67
Calcium P	22.84

Table 2: Characterization of organic manures under study.

Organic manure	PH	Total			Ratio		
		C (%)	H (%)	N (%)	P (%)	C/N	C/P
FYM	6.8	26.39	3.44	1.77	0.38	14.8	69.4
Oil cake	5.6	40.31	5.78	6.43	0.96	6.2	41.9
Pig manure	6.2	23.88	3.72	1.73	1.27	13.7	18.8
Range	5.6 - 6.8	23.88 - 40.31	3.44 - 5.78	1.73 - 6.43	0.38 - 1.27	6.2 - 14.8	18.8 - 69.4

Table 3: Extractable P (mg kg^{-1}) in an alluvial soil as influenced by organic manure addition and time of incubation.

Manures	Application Rate	Incubation period						
	(t ha^{-1})	2	72	168	336	480	1440	2160
FYM	4	0.3*	0.5	0.5	0.7	0.7	1.5	2.0
	40	0.8	1.2	1.5	1.8	2.1	2.9	3.3
	80	1.5	2.2	2.6	3.6	4.1	6.6	7.3
Oilcake	4	1.5	2.1	2.5	3.1	3.2	3.5	3.7
	40	3.6	3.9	4.1	4.7	4.8	5.6	5.8
	80	4.8	5.9	7.1	7.6	7.9	8.5	8.3
Pig manure	4	8.3	8.5	8.5	8.7	8.9	9.3	10.2
	40	9.1	9.1	9.0	9.7	10.0	12.1	12.3
	80	9.3	9.6	9.7	10.2	10.8	12.5	12.9

*Average of three replication.

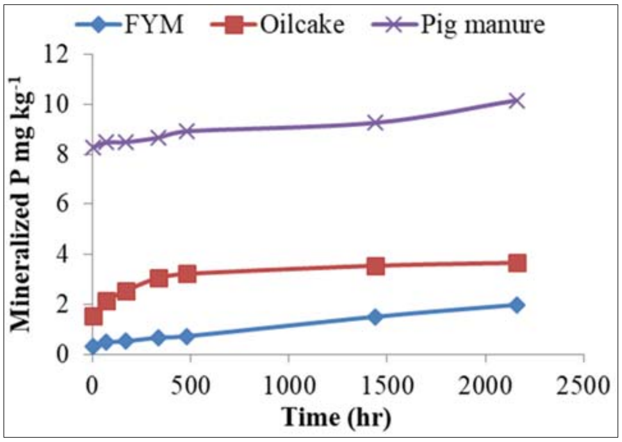

Fig 1: Net P mineralization of different organic manures in an alluvial soil amended @ 4 t ha^{-1}

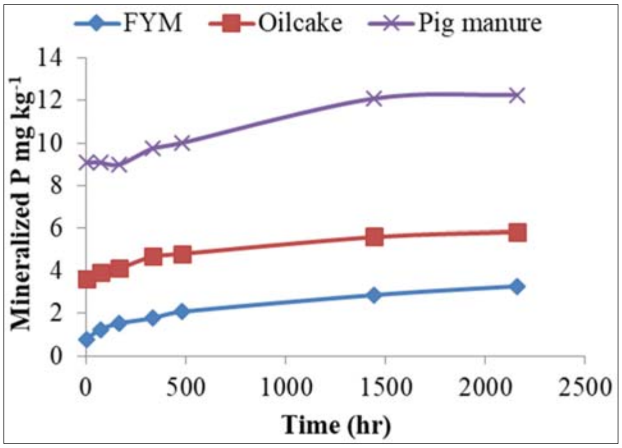

Fig 2: Net P mineralization of different organic manures in an alluvial soil amended @ 40 t ha^{-1}

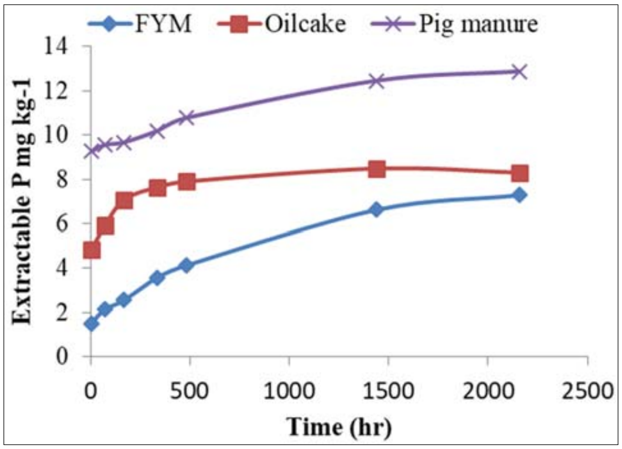

Fig 3: Net P mineralization of different organic manures in an alluvial soil amended @ 80 t ha^{-1}

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