Available Phosphorus in Soils Amended with Organic N-Enriched Composts during Periods of Incubation

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Abstract

Inorganic nitrogen (N) fertilizers, microbial inoculum and biologically-active substances are used to fortify composts which characteristically contain low amounts of N. The potentials of organic wastes from agriculture for N enrichment of composts were indicated by significant increase in soil N while there can be fortuitous improvement in the available phosphorus (P) contents on which information about the extent is lacking. In this study, composts: cow dung + sawdust (CDSD) and poultry droppings + sawdust (PDSD) were enriched with meals from bone (BN), blood (BM), hoof (HF) and horn (HN); and neem leaf (NM) and tithonia leaf (TM) to attain 150, 300, 450 and 600 g kg⁻¹ N and the available P was monitored at four-week intervals during 16 weeks of incubation in soil. Available P increased with all N sources and enrichment rates slightly at week 4 but highly from week 8 and for each source, the enrichment to 600 g kg⁻¹ N gave the highest values. The composts enriched to 450 and 600 g kg⁻¹ N gave 15-20 and 20-29 mg kg⁻¹ available P in week 12 and 16 respectively. CDSDBM and PDSDBHM enriched to 600 g kg⁻¹ N at week 4 and 8 respectively can be used for short-season crops while PDSDBM and PDSDNM enriched to 600 g kg⁻¹ N in week 12 and 16 respectively would be suitable for long-season crops. The PDSDNM enriched to 600 g kg⁻¹ N gave the highest available P (29.0 mg kg⁻¹) and was followed by PDSDBN and PDSDFHM at the same enrichment level, with 28.0 mg kg⁻¹ each. Although the PMSDNM enriched to 600 g kg⁻¹ N had the highest available P in week 16, the enriched composts with values exceeding 20 mg kg⁻¹ also have potentials for the cultivation of long-season vegetables.

Keywords: composts, agricultural wastes, enrichment, incubation, available P content

1. Introduction

Soils in the humid tropics contain low amounts of organic matter and available nutrients such that their productivity declines over time, especially under continuous cultivation (Zingore, Mafongoya & Giller, 2003). Crop yields have stagnated or declined due to increased soil degradation from anthropogenic sources, poor access to chemical fertilizers and a coping strategy of intensifying land use which accentuates nutrient ‘mining’. Since agriculture will remain a soil-based industry, nutrient depletion must be tackled in order to attain the desired increases in crop productivity. The declining crop yields from continuous use of chemical fertilizers are due to increased soil acidity and nutrient imbalance whereas several studies have indicated the positive effects of organic sources of nutrients on soil productivity (Anikwe, 2000). Thus, farming practices that encourage natural processes (minerals, manures, symbiosis etc) for nutrient supply are now being promoted.

Compost is organic manure produced from the controlled biological decomposition of organic materials that have been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth (Donahue, Miller & Schicichuna, 1990). Composting is used to manage high-volume solid organic wastes in an environment-friendly manner by converting them to useful soil amendments vital to organic farming as a source of organic matter and able to improve the chemical, physical and biological characteristics of soils (Rodale, 2012). All organic materials can be used for composting but the most common are cow dung, poultry droppings and sawdust. Cow dung consists of the fibrous material that passed through the animal’s digestive tract, some urea, mucus, as well as cellulose, lignin and hemicelluloses.
Thus, the resultant faecal matter is rich in minerals (Rodale, 2004) and has been used alone (Kekong, Ayuba & Ali, 2010) or in combination with other materials in the form of composts (Adeoeye, Ojobor & AdeOluwa, 2004) for soil maintenance. Poultry manure consists of the droppings from birds kept under battery cage and deep litter systems. Often, the droppings alone or mixed with the bedding materials are collected for use as manure. It contains all of the basic nutrients necessary for crops, especially N, P, potassium (K) and calcium (Ca), in amounts higher than all livestock classes and can be applied directly from the farm to the fields (Prabu, 2009), to be used alone (Kekong, Ayuba & Ali, 2010) or combined with other materials to produce composts (Enje & Ezeakolam, 2009). Sawdust is the solid organic waste, composed of fine particles of wood, generated during the sawing of sawn wood from timber logs in sawmills and splitting of planks in carpentry workshops. It contains very high carbon in the form of lignin, cellulose and pectin (BWNC, 2013). It is low in useful plant nutrients but can be used as mulch by orchardists, growers of small fruits and nursery men, composts serve as an alternative to clay caste litter fuel and the manufacture of particle boards.

Despite the age-long use and importance of composts, they contain low amounts of N which make the provision of additional N input inevitable and the search continues for materials which would be used to improve the contents and enhance the efficiency and quality of composts at low cost. Compost enrichment can involve the use of inorganic fertilizers and mineral ores to develop organo-mineral fertilizers (Zahir et al., 2007), microbial inoculum to hasten lignin decomposition (Manjunatha & Ravi, 2013) and biologically-active substances (Ahmad et al., 2009). The potentials of agricultural wastes, as organic N sources, for raising the N levels and which would fortuitously increase the P contents of composts (Adegbite & Olayinka, 2010) should be exploited.

The cattle industry is a source of abattoir wastes- bones, hoofs, blood and horns- which can serve as organic N sources to enrich composts. The 25 litres of blood obtained from a slaughtered cow can be dried and mashed into an inert powder (blood meal) containing 13.25 % N which is used to amend finished compost to increase its N content and balance the C: N ratio in compost piles. A slaughtered cow yields 70-90 kg bones which can be cleaned, dried and burnt or cooked and ground for conversion to bone meal as a slow release organic P fertilizer that contains Ca and little N (Scotts, 2012) at N-P-K formula of 4-12-0. The cooked, ground and dehydrated hooves and horns contain 12 % N and 2 % P which make the meals that are 12-2-0 NPK fertilizers.

Plants which produce large amounts of biomass are also needed to address the problems of soil fertility depletion in cropping systems (Vanlauwe & Giller, 2006) and there is the need to identify species whose leaves contain a large pool of nutrients, especially N and P usually at low concentrations in organic inputs and found in the vicinity to reduce labour cost. The neem tree (Azadirachta indica (A. Juss), family Meliaceae, is native to India, Pakistan and Bangladesh but grows in tropical and sub-tropical regions and has naturalized in Nigeria. The leaves contain 2.07 % N, 0.12 % P and 0.20 % K (Rafiu, 2012) and can be used to enrich composts, as mulch and green manure to neutralize soil acidity and provide nutrients and organic matter which improves soil structure and water holding capacity thereby enhancing soil fertility and health (Subbalakshmi et al., 2012; Satish, 2015). Mexican sunflower, wild sunflower [Tithonia diversifolia (Hemsley A. Gray)] is a succulent and soft shrub in the family Asteraceae and native to eastern Mexico and Central America but has a nearly pan-tropical distribution as an introduced weed species in crop farms and waste lands (Taxon, 2012). It accumulates large amounts of nutrients from the soil with the leaves containing 3.2 % N, 0.2 % P and 3.0 % K (Mugwe et al., 2007) which enhance the use as green manure, mulch and fertilizer and for composting.

The cattle abattoir wastes and leaves can be dried, ground into powder (meals) and used as materials to supplement the N content of composts (Fawole et al., 2019; Rhoades, 2020). All the nutrients taken up by the plants and animals which generate the wastes are contained in manures but the quality is often measured by the N contents whose eventual release through mineralization processes would provide the explanation for crop responses to manure application. This level of concern has not been expressed for P which also exists in the organic fraction and undergoes mineralization in a manner similar to N. Rock phosphate (RP) and single superphosphate (SSP) fertilizer are often applied to fortify composts with additional P. (Biswa & Narayanasamy, 2006; Zahir et al., 2007; Adegbite & Olayinka, 2010) noted that the enrichment of composts with the agricultural wastes fortuitously increased the total P contents. Therefore, the objectives of this study were to: enrich the composts produced from conventional materials- cow dung, poultry droppings and saw dust with blood, bone, hoof and horn meals, and neem leaf and tithonia leaf meals; and through incubation studies assess its effects on the availability of P in soils.

2. Materials and Methods

The study was carried out on the Teaching and Research Farm, Ekiti State University, Ado-Ekiti, Nigeria (latitude 7°31’N and longitude 5°13’E) in South-Western Nigeria. The site is within the rain forest zone and
experiences a tropical climate with distinct wet and dry seasons which span late March to October with a dry spell in August and November to early March respectively. The mean annual total rainfall is about 1,367 mm while the temperature is almost uniform throughout the year with very little deviation from the mean annual of 27°C. The agricultural economy is dominated by the cultivation of arable crops (yam, cassava, rice, maize, vegetables) and permanent tree crops (cocoa, kola and oil palm).

Poultry droppings, cattle wastes; blood, horns, hooves, bones and dung and sawdust were collected from designated farms and sawmill. Several branches of neem were cut and the leaves plucked while the young and succulent stalks and leaves of tithonia plants that were not flowering were cut and used. The cattle dung, poultry dung, sawdust, blood, bone, horn, hoof, neem leaf and tithonia leaf samples were air-dried, milled and analyzed for pH in water at 1:2 ratio, total carbon by chronic acid wet digestion method, total N by the micro-Kjeldahl method, total P, Ca, magnesium (Mg), K and sodium (Na) by wet digestion using concentrated nitric, perchloric and sulphuric acid mixture at a ratio of 25: 5: 5 respectively. P in the digestes was determined by vanado-molybdate method, Na and K were determined by flame photometry while Ca and Mg were determined by atomic absorption spectrophotometry (Udo et al., 2010). Cow dung and sawdust (CDS), poultry droppings and sawdust (PDS) were mixed at 1:1 ratio (v/v) in separate heaps 1.5 m wide and 1 m high, watered and turned fortnightly. At the end of 22 weeks, the organic N sources (blood, bone, hoof, horn, neem and tithonia meals) were mixed with the composts as shown in Table 1. The enrichment materials were added for the composts to attain 150, 300, 450 and 600 g kg⁻¹ N.

The soil used for the incubation study was a slightly acidic (pH 5.8 in KCl and 6.6 in water) sandy loam with 14.6 g kg⁻¹ organic matter content, 0.8 g kg⁻¹ total N, 13.0 mg kg⁻¹ available P while the exchangeable bases: K, Ca, Mg and Na were 0.3, 7.0, 1.8 and 0.1 cmol kg⁻¹ respectively. Two kilogrammes (2 kg) of topsoil were weighed into 2.5 litre bowls and each of the enriched composts, at the rate of 30 t ha⁻¹ was thoroughly mixed with the soil, moistened and covered with black polythene sheets and kept in a cool place. Each treatment was in four sets to accommodate the monitoring of available P contents in samples at 4, 8, 12 and 16 weeks of incubation.

Table 1. Treatment combinations and their description

| Treatments | Description                                      |
|------------|--------------------------------------------------|
| CDS        | Cow dung + sawdust                               |
| CDSDBM     | Cow dung + sawdust + blood meal                  |
| CDSDBN     | Cow dung + sawdust + bone meal                   |
| CSDHNM     | Cow dung + sawdust + horn meal                   |
| CSDHF      | Cow dung + sawdust + hoof meal                   |
| CSDTM      | Cow dung + sawdust + tithonia leaf meal          |
| CDSDNM     | Cow dung + sawdust + neem leaf meal              |
| PDS        | Poultry droppings + sawdust                      |
| PDSBM      | Poultry droppings + sawdust + blood meal         |
| PDSBN      | Poultry droppings + sawdust + bone meal          |
| PDSHN      | Poultry droppings + sawdust + horn meal          |
| PDSHF      | Poultry droppings + sawdust + hoof meal          |
| PDSMT      | Poultry droppings + sawdust + tithonia leaf meal |
| PDSNMM     | Poultry droppings + sawdust + neem leaf meal     |

3. Results

Table 2 shows the chemical properties of the composting materials, composts and the enrichment materials. PD, CD and SD were alkaline (pH=8.0-8.4). Poultry dung (PD) gave the highest total N, K and Ca values while the highest total P was recorded from cow dung (CD). The recorded Mg contents varied between 6.0 and 6.7 g kg⁻¹ in the three composting materials. The results of the analysis of the enrichment materials showed that BN, HN and TM were alkaline with BN having a pH of 10.5 while both HN and TM had 8.2. Other enrichment materials; BM, HF and NM were slightly acidic (pH=6.2-6.5). The highest N (98.7 g kg⁻¹) was obtained in NM while BN contained the least N (2.0 g kg⁻¹). Highest total P was recorded in HN and BN (25.6 and 24.1 g kg⁻¹ respectively) while the other enrichment materials contained P in the order TM > NM > HF > BM. Hoof (HF) and blood meals (BM) contained the highest Ca content. The Mg status was within 5.8-6.6 g kg⁻¹ in the enrichment materials while K and Na contents varied between 4.1 and 5.1g kg⁻¹ and 0.5-1.1 g kg⁻¹ respectively in the materials. The matured composts were alkaline (CDSD= 8.4 and PDS= 8.2); Total N, Ca, Mg, K and Na values were higher in
CDSD while PDSD contained higher P content.

The available P contents of soils to which composts enriched with organic N sources at various levels were added and incubated for 4, 8, 12 and 16 weeks are shown in Figs. 1-4. All the treatments showed increases in available P levels with time of incubation. Available P content of the soils which received CDSD and PDSD controls was 5.4 and 6.1 mg kg\(^{-1}\) in week 4 which increased to 15.0 and 14.5 mg kg\(^{-1}\) in week 16 respectively. Compared to the control, soil available P was similar for all the composts enriched to 150 g kg\(^{-1}\) N; CDSDBM, CDSDHM, CDSDHF and CDSDNM enriched to 300 g kg\(^{-1}\) N; CDSDBN, CDSDHN and CDSDHF enriched to 450 g kg\(^{-1}\) N and CDSDBN enriched to 600 g kg\(^{-1}\) N in week 4.

In week 8, available P increased at the higher rates of N enrichment except in soils treated with CDSDBN and CDSDHN enriched to 150 g kg\(^{-1}\) N and CDSDBN enriched to 300 g kg\(^{-1}\) N which were not different from the CDSD control. The available P content of the CDSD control was lower than only CDSDNM and CDSDTM enriched to 150 g kg\(^{-1}\) N but similar to CDSDBN and CDSDHN enriched to 300 g kg\(^{-1}\) N in week 12. In week 16, the application of CDSDNM enriched to all the N rates gave values that differed from the control whereas CDSDHN and CDSDFH enriched to 150 and 300 g kg\(^{-1}\)N and CDSDHF enriched to 450 and 600 g kg\(^{-1}\) N contained values lower than or similar to the control. All the treatments contained available P similar to the PDSD control in week 4 and higher values in week 8. In week 12, PDSD control gave values similar to the application of composts enriched to attain 150 g kg\(^{-1}\) N with all the organic sources and PDSDHN and PDSDFH enriched to 300 and 450 g kg\(^{-1}\) N while the PDSD control gave lower available P in week 16.

The available P content increased with the level of N enrichment in each organic material and the longer the incubation period, the higher was the content and the magnitude of increase. For each time of incubation, the application of CDSDHN enriched to 150 g kg\(^{-1}\) N gave the least available P values while CDSDBM, CDSDBN, CDSDBM and CDSDNM enriched to 600 g kg\(^{-1}\) N gave the highest values at 4, 8, 12 and 16 weeks of incubation respectively. PDSDBN enriched to 450 g kg\(^{-1}\) N and PDSDNM, PDSDBM and PDSDFM enriched to 600 g kg\(^{-1}\) N contained the highest available P at 4, 8, 12 and 16 weeks respectively. At 16 weeks, the PMSDNM enriched to 600 g kg\(^{-1}\) N had the highest available P value of 29.0 mg kg\(^{-1}\) while CDSDHN enriched to attain 150 g kg\(^{-1}\) N contained the least available P value of 16.2 mg kg\(^{-1}\).

Table 2. Some Chemical Properties of the Compost Materials, Composts and the Organic Wastes used for N Enrichment

| Parameters | Blood meal | Bone meal | Hoof meal | Horn meal | Tithonia meal | Neem meal | Cow dung | Poultry droppings | Saw dust | CDSD Compost | PDSD Compost |
|------------|------------|-----------|-----------|-----------|---------------|------------|----------|-----------------|----------|---------------|---------------|
| pH         | 6.2        | 10.5      | 6.2       | 8.2       | 8.2           | 6.5        | 8.0      | 8.4             | 8.4      | 8.4           | 8.2           |
| Total N (g/kg) | 78.8      | 2.0       | 58.1      | 44.2      | 82.0          | 98.7       | 53.9     | 79.2            | 0.9      | 64.0         | 42.2          |
| Total C (g/kg) | 325.6     | 7.8       | 405.4     | 182.6     | 339.1         | 407.8      | 222.9    | 327.2           | 334.3    | 258.0        | 158.0         |
| Total P (g/kg) | 0.3       | 24.1      | 0.9       | 25.6      | 2.7           | 1.2        | 26.8     | 8.6             | 0.2      | 10.0         | 23.0          |
| Ca (g/kg)   | 12.2       | 10.9      | 12.1      | 10.0      | 9.7           | 9.2        | 9.5      | 13.1            | 10.4     | 13.0         | 11.5          |
| Mg (g/kg)   | 6.1        | 5.8       | 6.6       | 6.0       | 6.2           | 5.9        | 6.0      | 6.7             | 6.4      | 6.8          | 6.2           |
| K (g/kg)    | 4.4        | 4.1       | 5.0       | 4.1       | 5.1           | 4.1        | 4.4      | 5.2             | 4.8      | 6.1          | 5.4           |
| Na (g/kg)   | 1.1        | 0.8       | 0.7       | 0.7       | 0.5           | 0.5        | 0.8      | 0.8             | 0.5      | 1.3          | 0.4           |

CDSD= Cow dung + Saw dust
PDSD=Poultry droppings + Sawdust
Legend
C0 Control
C1 CDSD Soil alone
C2 CDSDBM at 150 g kg\(^{-1}\) N Cow dung + Sawdust
C3 CDSDBM at 150 g kg\(^{-1}\) N Cow dung + Sawdust enriched with Bone meal at 150 g kg\(^{-1}\) N
C4 CDSDHM at 150 g kg\(^{-1}\) N Cow dung + Sawdust enriched with Hoof meal at 150 g kg\(^{-1}\) N
C5 CDSDHN at 150 g kg\(^{-1}\) N Cow dung + Sawdust enriched with Horn meal at 150 g kg\(^{-1}\) N
C6 CDSDNM at 150 g kg\(^{-1}\) N Cow dung + Sawdust enriched with Neem leaf meal at 150 g kg\(^{-1}\) N
C7 CDSDTM at 150 g kg\(^{-1}\) N Cow dung + Sawdust enriched with Tithonia meal at 150 g kg\(^{-1}\) N
C26 PDS Soil alone
C27 PDSDBM at 150 g kg\(^{-1}\) N Poultry droppings + Sawdust
C28 PDSDBN at 150 g kg\(^{-1}\) N Poultry droppings + Sawdust enriched with Bone meal at 150 g kg\(^{-1}\) N
C29 PDSDBM at 150 g kg\(^{-1}\) N Poultry droppings + Sawdust enriched with Bone meal at 150 g kg\(^{-1}\) N
C30 PDSDBN at 150 g kg\(^{-1}\) N Poultry droppings + Sawdust enriched with Bone meal at 150 g kg\(^{-1}\) N
C31 PDSDBN at 150 g kg\(^{-1}\) N Poultry droppings + Sawdust enriched with Bone meal at 150 g kg\(^{-1}\) N
C32 PDSDBM at 150 g kg\(^{-1}\) N Poultry droppings + Sawdust enriched with Bone meal at 150 g kg\(^{-1}\) N

Figure 1. Available P measured monthly during incubation for treatments at 150 g kg\(^{-1}\) N enrichment level.

Figure 2. Available P measured monthly during incubation for treatments at 300 g kg\(^{-1}\) N enrichment level.
Legend

C0  Control  Soil alone
C1  CDSD  Cow dung + Sawdust
C8  CDSDBM at 300 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Blood meal at 300 g kg\(^{-1}\) N
C9  CDSDBN at 300 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Bone meal at 300 g kg\(^{-1}\) N
C10  CDSDHM at 300 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Hoof meal at 300 g kg\(^{-1}\) N
C11  CDSDBN at 300 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Bone meal at 300 g kg\(^{-1}\) N
C12  CDSDBM at 300 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Blood meal at 300 g kg\(^{-1}\) N
C13  CDSDBN at 300 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Bone meal at 300 g kg\(^{-1}\) N
C26  PDS  Poultry droppings + Sawdust
C33  PDSDBM at 300 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Blood meal at 300 g kg\(^{-1}\) N
C34  PDSDBN at 300 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Bone meal at 300 g kg\(^{-1}\) N
C35  PDSDHM at 300 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Hoof meal at 300 g kg\(^{-1}\) N
C36  PDSDBN at 300 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Bone meal at 300 g kg\(^{-1}\) N
C37  PDSDBM at 300 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Blood meal at 300 g kg\(^{-1}\) N
C38  PDSDBN at 300 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Bone meal at 300 g kg\(^{-1}\) N

Figure 3. Available P measured monthly during incubation for treatments at 450 g kg\(^{-1}\) N enrichment level

Legend

C0  Control  Soil alone
C1  CDSD  Cow dung + Sawdust
C14  CDSDBM at 450 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Blood meal at 450 g kg\(^{-1}\) N
C15  CDSDBN at 450 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Bone meal at 450 g kg\(^{-1}\) N
C16  CDSDHM at 450 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Hoof meal at 450 g kg\(^{-1}\) N
C17  CDSDBN at 450 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Bone meal at 450 g kg\(^{-1}\) N
C18  CDSDBM at 450 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Blood meal at 450 g kg\(^{-1}\) N
C19  CDSDBN at 450 g kg\(^{-1}\) N  Cow dung + Sawdust enriched with Bone meal at 450 g kg\(^{-1}\) N
C26  PDS  Poultry droppings + Sawdust
C39  PDSDBM at 450 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Blood meal at 450 g kg\(^{-1}\) N
C40  PDSDBN at 450 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Bone meal at 450 g kg\(^{-1}\) N
C41  PDSDHM at 450 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Hoof meal at 450 g kg\(^{-1}\) N
C42  PDSDBN at 450 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Bone meal at 450 g kg\(^{-1}\) N
C43  PDSDBM at 450 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Blood meal at 450 g kg\(^{-1}\) N
C44  PDSDBN at 450 g kg\(^{-1}\) N  Poultry droppings + Sawdust enriched with Bone meal at 450 g kg\(^{-1}\) N
4. Discussion

The replenishment of nutrients continuously removed by crops and the reversal of the usually negative nutrient budgets of soils in order to optimize productivity with chemical fertilizers has been bedevilled by high prices and lack of access due to product scarcity, especially in Nigeria, making the use uneconomical to subsistence farmers (Liverpool-Tasie et al., 2010). The soil application of the wastes generated in animal industries is an environment-friendly means of disposal even as the availability of several organic materials has favoured composting which made composts popular as alternative sources of nutrients in crop production systems (Adeleye & Ayeni, 2010). Thus, the preparation of composts from cheap organic materials and the use for crop production are strengthened by the ability to maintain soil fertility and dispose livestock industry wastes which would otherwise constitute environmental pollution threats.

In this study, the composts prepared as cow dung + sawdust (CDSD) and poultry droppings + sawdust (PBSD) had become dark brown/black at 22 weeks and were slightly alkaline as an indication of maturity and readiness for use (Muller-Samann & Kotschi, 1994). The pH values of the composts were not different from those of the composting materials. This is probably because Ca, Mg and K, mainly associated with acidic or alkaline conditions, do not have organic phases despite their roles in various metabolic processes and would not be substantially affected by the microbial breakdown of the organic compounds in plant matter and animal wastes. The total P content of the CDSD was low compared to the cow dung which could be attributed to dilution effect of the sawdust. N and P are utilized for the rapid growth and multiplication of the microbial populations involved in organic matter decomposition but the processes involved would hardly engender such substantial losses of P.
The total P in PDSD was higher than in the poultry droppings. The autochthonous microbial population which ties up P in the tissues during decomposition of the organic materials is replaced by facultative bacteria as the compost matures (Brady & Weil, 2004) such that the P is not lost and so would remain in the compost.

The increase in available soil P content across the treatments throughout the incubation period, even where only the CDSD and PDSD controls were applied, indicates mineralization in the composts but which was little at week 4 and substantial as from week 8 of incubation. Since incubation involved keeping the soil-compost mixtures moist, the microbes present in the soils were active in decomposition of the organic compounds resulting in P mineralization. There were different peaks of available P for the enriched composts indicating that the nutrient content and availability vary widely among compost types and are dependent on compost composition and compost maturity (Harrison & Henry, 1994). However, the steady increase of available P obtained in most of the enriched composts, especially those based on CDSD, could be attributed to the addition of N through the organic N sources used to enrich the composts (Adegbite & Olayinka, 2010).

The patterns of P availability over the periods of incubation indicate that CDSDBM enriched to 600 g kg\(^{-1}\) N with the highest available P at 4 weeks into incubation and PMSDNM enriched to 600 g kg\(^{-1}\) N which gave the highest P value at 8 weeks into incubation would be suitable for the production of short-season crops that are ready for harvesting between 4 to 8 weeks after planting such as leaf vegetables: leaf amaranth (Amaranthus spp), jute mallow (Corchorus olitorius), Celosia argentea, water leaf (Talinum fruticosum) etc. The PMSDBM enriched to 600 g kg\(^{-1}\) N which had the highest available P at 12 weeks and PMSDNM at 600 g kg\(^{-1}\) N with the highest available P at 16 weeks incubation would be recommended for long-season crops, especially leaf and fruit vegetables such as okra, tomato, sweet corn, eggplant, egusi (Citrullus lanatus), worowo (Senecio biafrae), fluted pumpkin (Telfairia occidentalis) etc.

5. Summary and Conclusion

Some organic materials were identified as sources for compost N-enrichment. The fortuitous increase in available P was studied in soils to which mature composts enriched to 150, 300, 450, and 600 g kg\(^{-1}\) N equivalent with cattle abattoir wastes (blood, bone, horn, hoof meals), neem leaf and tithonia leaf meals were added and incubated for 16 weeks. The available P contents increased to the highest values in all the organic N sources enriched to 600 g kg\(^{-1}\) N such that CDSDBM and PMSDNM with the highest available P in week 4 and 8 respectively would be suitable for short-season crops while PMSDBM and PMSDNM had the highest available P in week 12 and 16 respectively and would be recommended for long-season crops, especially leaf and fruit vegetables.

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