

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

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Received: October 8, 2019

Accepted: September 18, 2020

Online Published: July 20, 2021

doi:10.5539/jps.v10n2p20

URL: <https://doi.org/10.5539/jps.v10n2p20>

## 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 (CSDS) and poultry droppings + sawdust (PDS) 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<sup>-1</sup> 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<sup>-1</sup> N gave the highest values. The composts enriched to 450 and 600 g kg<sup>-1</sup> N gave 15-20 and 20-29 mg kg<sup>-1</sup> available P in week 12 and 16 respectively. CSDSBN and PDSHF enriched to 600 g kg<sup>-1</sup> N at week 4 and 8 respectively can be used for short-season crops while PDSBN and PDSNM enriched to 600 g kg<sup>-1</sup> N in week 12 and 16 respectively would be suitable for long-season crops. The PDSNM enriched to 600 g kg<sup>-1</sup> N gave the highest available P (29.0 mg kg<sup>-1</sup>) and was followed by PDSBN and PDSHF at the same enrichment level, with 28.0 mg kg<sup>-1</sup> each. Although the PMSDNM enriched to 600 g kg<sup>-1</sup> N had the highest available P in week 16, the enriched composts with values exceeding 20 mg kg<sup>-1</sup> 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 system along other liquid digesta left after the fermentation, absorption and filtration, then acidified and absorbed again. The composition is mainly carbon, hydrogen, oxygen, nitrogen (N), phosphorus (P) and salts, cells sloughed off as the digesta went through the 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 (Adeoye, 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 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 (Eneje & Ezeakolam, 2009). Sawdust is the solid organic waste, composed of fine particles of wood, generated during the production 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 milled 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. (Biswas & 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 chromic 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 digests 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<sup>-1</sup> 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<sup>-1</sup> organic matter content, 0.8 g kg<sup>-1</sup> total N, 13.0 mg kg<sup>-1</sup> available P while the exchangeable bases: K, Ca, Mg and Na were 0.3, 7.0, 1.8 and 0.1 cmol kg<sup>-1</sup> 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<sup>-1</sup> 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
CSDSHN	Cow dung + sawdust + horn meal
CSDSHF	Cow dung + sawdust + hoof meal
CSDSTM	Cow dung + sawdust + tithonia leaf meal
CSDSNM	Cow dung + sawdust + neem leaf meal
PDS	Poultry droppings + sawdust
PDSDBM	Poultry droppings + sawdust + blood meal
PDSDBN	Poultry droppings + sawdust + bone meal
PDSHDN	Poultry droppings + sawdust + horn meal
PDSHF	Poultry droppings + sawdust + hoof meal
PDSSTM	Poultry droppings + sawdust + tithonia leaf meal
PDSNM	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<sup>-1</sup> 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<sup>-1</sup>) was obtained in NM while BN contained the least N (2.0 g kg<sup>-1</sup>). Highest total P was recorded in HN and BN (25.6 and 24.1 g kg<sup>-1</sup> 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<sup>-1</sup> in the enrichment materials while K and Na contents varied between 4.1 and 5.1g kg<sup>-1</sup> and 0.5-1.1 g kg<sup>-1</sup> respectively in the materials. The matured composts were alkaline (CDS= 8.4 and PDS= 8.2); Total N, Ca, Mg, K and Na values were higher in

CDSO while PDSO contained higher total 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 CDSO and PDSO controls was 5.4 and 6.1 mg kg<sup>-1</sup> in week 4 which increased to 15.0 and 14.5 mg kg<sup>-1</sup> in week 16 respectively. Compared to the control, soil available P was similar for all the composts enriched to 150 g kg<sup>-1</sup> N; CDSDBM, CDSO, CDSO, CDSO and CDSO enriched to 300 g kg<sup>-1</sup> N; CDSDBN, CDSO and CDSO enriched to 450 g kg<sup>-1</sup> N and CDSDBN enriched to 600 g kg<sup>-1</sup> N in week 4.

In week 8, available P increased at the higher rates of N enrichment except in soils treated with CDSDBN and CDSO enriched to 150 g kg<sup>-1</sup> N and CDSDBN enriched to 300 g kg<sup>-1</sup> N which were not different from the CDSO control. The available P content of the CDSO control was lower than only CDSO and CDSO enriched to 150 g kg<sup>-1</sup> N but similar to CDSDBN and CDSO enriched to 300 g kg<sup>-1</sup> N in week 12. In week 16, the application of CDSO enriched to all the N rates gave values that differed from the control whereas CDSO and CDSO enriched to 150 and 300 g kg<sup>-1</sup> N and CDSO enriched to 450 and 600 g kg<sup>-1</sup> N contained values lower than or similar to the control. All the treatments contained available P similar to the PDSO control in week 4 and higher values in week 8. In week 12, PDSO control gave values similar to the application of composts enriched to attain 150 g kg<sup>-1</sup> N with all the organic sources and PDSO and PDSO enriched to 300 and 450 g kg<sup>-1</sup> N while the PDSO 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 CDSO enriched to 150 g kg<sup>-1</sup> N gave the least available P values while CDSDBM, CDSDBN, CDSDBM and CDSO enriched to 600 g kg<sup>-1</sup> N gave the highest values at 4, 8, 12 and 16 weeks of incubation respectively. PDSDBN enriched to 450 g kg<sup>-1</sup> N and PDSO, PDSDBM and PDSO enriched to 600 g kg<sup>-1</sup> N contained the highest available P at 4, 8, 12 and 16 weeks respectively. At 16 weeks, the PMSO enriched to 600 g kg<sup>-1</sup> N had the highest available P value of 29.0 mg kg<sup>-1</sup> while CDSO enriched to attain 150 g kg<sup>-1</sup> N contained the least available P value of 16.2 mg kg<sup>-1</sup>.

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	CDSO Compost	PDSO 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

CDSO= Cow dung + Sawdust

PDSO=Poultry droppings + Sawdust

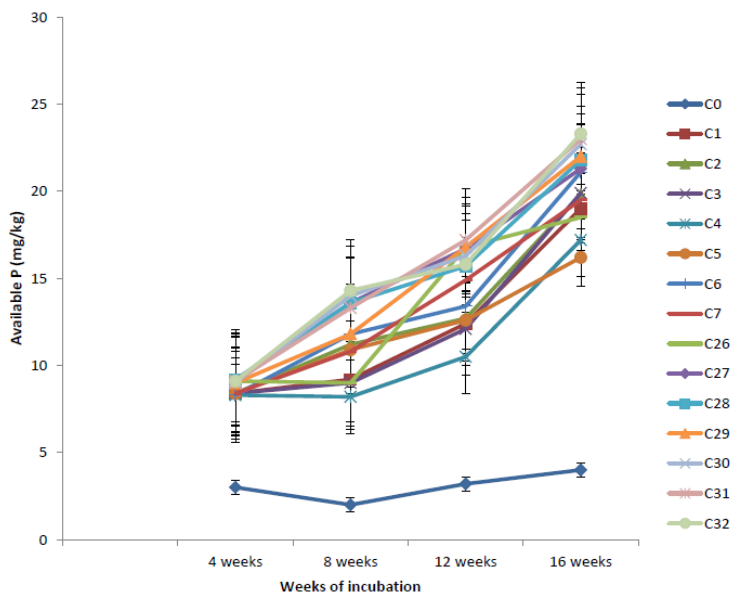


Figure 1. Available P measured monthly during incubation for treatments at 150 g kg<sup>-1</sup> N enrichment level

**Legend**

- |  |  |
|--|--|
| C0 Control                             | Soil alone   |
| C1 CDS                                 | Cow dung + Sawdust   |
| C2 CDSDBM at 150 g kg <sup>-1</sup> N  | Cow dung + Sawdust enriched with Blood meal at 150 g kg <sup>-1</sup> N              |
| C3 CDSDBM at 150 g kg <sup>-1</sup> N  | Cow dung + Sawdust enriched with Bone meal at 150 g kg <sup>-1</sup> N               |
| C4 CDSDHM at 150 g kg <sup>-1</sup> N  | Cow dung + Sawdust enriched with Hoof meal at 150 g kg <sup>-1</sup> N               |
| C5 CDSDHN at 150 g kg <sup>-1</sup> N  | Cow dung + Sawdust enriched with Horn meal at 150 g kg <sup>-1</sup> N               |
| C6 CDSDNM at 150 g kg <sup>-1</sup> N  | Cow dung + Sawdust enriched with Neem leaf meal at 150 g kg <sup>-1</sup> N          |
| C7 CSDTM at 150 g kg <sup>-1</sup> N   | Cow dung + Sawdust enriched with Tithonia meal at 150 g kg <sup>-1</sup> N           |
| C26 PDS                                | Poultry droppings + Sawdust  |
| C27 PDSDBM at 150 g kg <sup>-1</sup> N | Poultry droppings + Sawdust enriched with Blood meal at 150 g kg <sup>-1</sup> N     |
| C28 PDSDBN at 150 g kg <sup>-1</sup> N | Poultry droppings + Sawdust enriched with Bone meal at 150 g kg <sup>-1</sup> N      |
| C29 PDSDHM at 150 g kg <sup>-1</sup> N | Poultry droppings + Sawdust enriched with Hoof meal at 150 g kg <sup>-1</sup> N      |
| C30 PDSDHN at 150 g kg <sup>-1</sup> N | Poultry droppings + Sawdust enriched with Horn meal at 150 g kg <sup>-1</sup> N      |
| C31 PDSDNM at 150 g kg <sup>-1</sup> N | Poultry droppings + Sawdust enriched with Neem leaf meal at 150 g kg <sup>-1</sup> N |
| C32 PSDTM at 150 g kg <sup>-1</sup> N  | Poultry droppings + Sawdust enriched with Tithonia meal at 150 g kg <sup>-1</sup> N. |

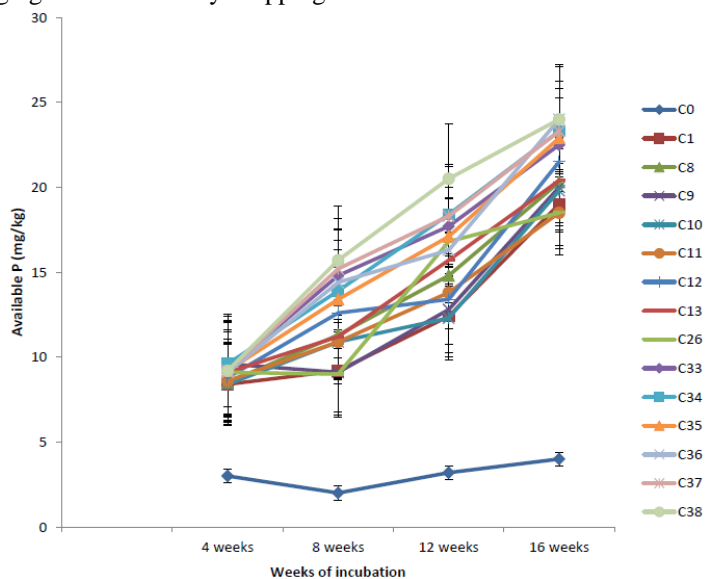


Figure 2. Available P measured monthly during incubation for treatments at 300 g kg<sup>-1</sup> N enrichment level

**Legend**

- C0 Control
- C1 CDS
- C8 CDSDBM at 300 g kg<sup>-1</sup> N
- C9 CDSDBN at 300 g kg<sup>-1</sup> N
- C10 CDSDHM at 300 g kg<sup>-1</sup> N
- C11 CDSDHN at 300 g kg<sup>-1</sup> N
- C12 CDSDNM at 300 g kg<sup>-1</sup> N
- C13 CSDTM at 300 g kg<sup>-1</sup> N
- C26 PDS
- C33 PDSDBM at 300 g kg<sup>-1</sup> N
- C34 PDSDBN at 300 g kg<sup>-1</sup> N
- C35 PDSDHM at 300 g kg<sup>-1</sup> N
- C36 PDSDHN at 300 g kg<sup>-1</sup> N
- C37 PDSDNM at 300 g kg<sup>-1</sup> N
- C38 PDSDTM at 300 g kg<sup>-1</sup> N

- Soil alone
- Cow dung + Sawdust
- Cow dung + Sawdust enriched with Blood meal at 300 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Bone meal at 300 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Hoof meal at 300 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Horn meal at 300 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Neem leaf meal at 300 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Tithonia meal at 300 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust
- Poultry droppings + Sawdust enriched with Blood meal at 300 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Bone meal at 300 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Hoof meal at 300 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Horn meal at 300 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Neem leaf meal at 300 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Tithonia meal at 300 g kg<sup>-1</sup> N.

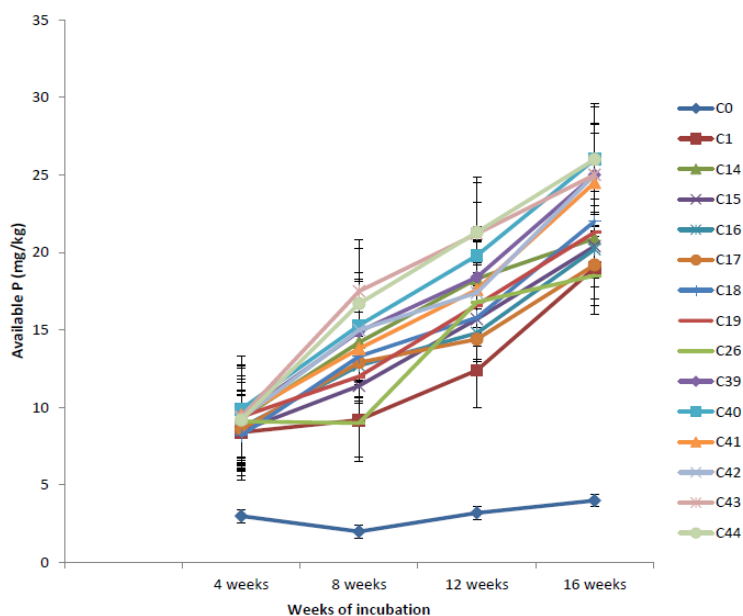


Figure 3. Available P measured monthly during incubation for treatments at 450 g kg<sup>-1</sup> N enrichment level

**Legend**

- C0 Control
- C1 CDS
- C14 CDSDBM at 450 g kg<sup>-1</sup> N
- C15 CDSDBN at 450 g kg<sup>-1</sup> N
- C16 CDSDHM at 450 g kg<sup>-1</sup> N
- C17 CDSDHN at 450 g kg<sup>-1</sup> N
- C18 CDSDNM at 450 g kg<sup>-1</sup> N
- C19 CSDTM at 450 g kg<sup>-1</sup> N
- C26 PDS
- C39 PDSDBM at 450 g kg<sup>-1</sup> N
- C40 PDSDBN at 450 g kg<sup>-1</sup> N
- C41 PDSDHM at 450 g kg<sup>-1</sup> N
- C42 PDSDHN at 450 g kg<sup>-1</sup> N
- C43 PDSDNM at 450 g kg<sup>-1</sup> N
- C44 PDSDTM at 450 g kg<sup>-1</sup> N

- Soil alone
- Cow dung + Sawdust
- Cow dung + Sawdust enriched with Blood meal at 450 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Bone meal at 450 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Hoof meal at 450 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Horn meal at 450 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Neem leaf meal at 450 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Tithonia meal at 450 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust
- Poultry droppings + Sawdust enriched with Blood meal at 450 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Bone meal at 450 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Hoof meal at 450 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Horn meal at 450 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Neem leaf meal at 450 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Tithonia meal at 450 g kg<sup>-1</sup> N.

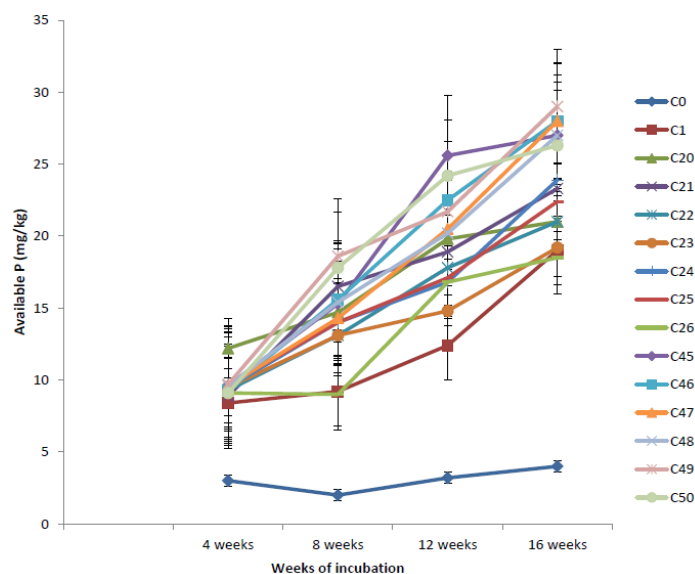


Figure 4. Available P measured monthly during incubation for treatments at 600 g kg<sup>-1</sup> N enrichment level

**Legend**

- C0 Control
- C1 CDS
- C20 CDSDBM at 600 g kg<sup>-1</sup> N
- C21 CDSDBN at 600 g kg<sup>-1</sup> N
- C22 CDSDHM at 600 g kg<sup>-1</sup> N
- C23 CDSDHN at 600 g kg<sup>-1</sup> N
- C24 CDSDNM at 600 g kg<sup>-1</sup> N
- C25 CDSDTM at 600 g kg<sup>-1</sup> N
- C26 PDSD
- C45 PDSDBM at 600 g kg<sup>-1</sup> N
- C46 PDSDBN at 600 g kg<sup>-1</sup> N
- C47 PDSDHM at 600 g kg<sup>-1</sup> N
- C48 PDSDHN at 600 g kg<sup>-1</sup> N
- C49 PDSDNM at 600 g kg<sup>-1</sup> N
- C50 PDSDTM at 600 g kg<sup>-1</sup> N
- Soil alone
- Cow dung + Sawdust
- Cow dung + Sawdust enriched with Blood meal at 600 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Bone meal at 600 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Hoof meal at 600 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Horn meal at 600 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Neem leaf meal at 600 g kg<sup>-1</sup> N
- Cow dung + Sawdust enriched with Tithonia meal at 600 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust
- Poultry droppings + Sawdust enriched with Blood meal at 600 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Bone meal at 600 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Hoof meal at 600 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Horn meal at 600 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Neem leaf meal at 600 g kg<sup>-1</sup> N
- Poultry droppings + Sawdust enriched with Tithonia meal at 600 g kg<sup>-1</sup> 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 (CDS) and poultry droppings + sawdust (PDSD) 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 CDS 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 PDSM 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 CDSM and PDSM 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 CDSM, 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 CDSBM enriched to 600 g kg<sup>-1</sup> N with the highest available P at 4 weeks into incubation and PMSDNM enriched to 600 g kg<sup>-1</sup> 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<sup>-1</sup> N which had the highest available P at 12 weeks and PMSDNM at 600 g kg<sup>-1</sup> 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<sup>-1</sup> 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<sup>-1</sup> N such that CDSBM 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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