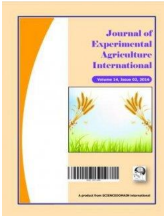

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Soil Nitrogen Contents as Affected by Composts Enriched with Organic Nitrogen Sources

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Authors' contributions

This work was carried out in collaboration among all authors. Author GOA designed the study. Author FOF wrote the protocol and wrote the first draft of the manuscript. Author OJA reviewed the experimental design and all drafts of the manuscript. Author FOF managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Information is scanty on the potentials of agricultural wastes to enrich composts whose low nitrogen (N) content limits their use in organic farming. This study involved enriching composts - cow dung + sawdust (CDSD) and poultry droppings + sawdust (PDSD) with N from bone, blood, hoof and horn meals; and neem leaf and tithonia leaf meals and their incubation in the soil for 16 weeks. Cow dung and sawdust (CDSD), poultry manure and sawdust (PMSD) in 1:1 ratios were composted in separate heaps and samples taken for nutrient analysis at 2 and 22 weeks of composting. The composts were enriched with Bone, Blood, Hoof and Horn of cattle; Neem leaf and Tithonia leaf meals to obtain the following: CDSD + bone (CDSDBN), CDSD + blood (CDSDBM), CDSD + hoof (CDSDHM), CDSD + horn (CDSDHN), CDSD + neem (CDSDNM) and CDSD + tithonia (CDSDTM); PMSD + bone (PMSDBN), PMSD + blood (PMSDBM), PMSD + hoof (PMSDHM), PMSD + horn (PMSDHN), PMSD + neem (PMSDNM) and PMSD + tithonia (PMSDTM). The enrichment was madeto attain 100, 200, 300 and 500g kg^{-1} N. Each treatment at 30 t ha^{-1} was incubated for sixteen weeks to monitor the nutrient release at four-week intervals. Total N contents monitored at four-

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week intervals of incubation showed enrichment in 74.0 and 83.0% of CDSD and PDSD compared to the respective controls. N contents were highest in 21, 0, 1 and 28 composts incubated for 4, 8, 12 and 16 weeks respectively. At 4 weeks, CDSD enriched to 500 g kg^{-1} N from blood meal (CDSDBM) and bone meal (CDSDBN) contained 10.5 and 9.2 gkg^{-1} total N while PDSD enriched to 50 g kg^{-1} N from bone meal (PDSDBN) and tithonia leaf meal (PDSDTM) contained 9.3 and 8.6 g kg^{-1} total N. These are suitable for the cultivation of short-season leaf vegetables. N content reduced at 8 weeks of incubation and increased at 12 and 16 weeks. Only CDSD enriched with neem leaf meal (CDSDNM at all N rates) showed increase in N content with time of incubation. CDSDNM and PDSDBM at 50 g kg^{-1} N contained the highest total N at 16 weeks of incubation and should be recommended for the cultivation of long-season vegetables.

Keywords: Composts; agricultural wastes; enrichment; incubation; nitrogen 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 when subjected to continuous cultivation [1]. This depletion of soil nutrients and the other causes of land degradation- soil erosion, salinization and waterlogging- have taken out 5-10 million ha of agricultural lands [2]. In Africa, the decline in soil fertility is very rapid, yet it is on this fragile resources base that expectations for increased crop production are built even in the face of a growing concern over soil degradation from anthropogenic sources. Besides, the farmers have the greatest difficulty in providing supplementary plant nutrients from chemical fertilizers due to lack of access to the products. The coping strategy is to intensify land use which accentuates nutrient ‘mining’ of soils such that crop production has stagnated or is on a decline. Nutrient depletion must be tackled otherwise the deterioration in agricultural productivity will undermine the foundations of sustainable economic growth. Thus, since agriculture will remain a soil-based industry, the desired increases in crop productivity are unlikely unless adequate and balanced supply of nutrients is ensured.

The continued use of chemical fertilizers in soils of the tropics has caused crop yield declines due to increased soil acidity and nutrient imbalance [3,4] whereas several studies have indicated the positive effects of organic wastes on soil productivity [5]. The fad is now to demand food items produced by organic farming practices that do not involve the application of chemical fertilizers but encourage natural processes for nutrient supply (minerals, manures, symbiosis etc). 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. The process of composting is used to manage the high volume of solid organic wastes in an environment-sound way by converting it 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.

Despite the age-long use and importance of composts, they contain low amounts of N such that getting enough N when plants need it most is perhaps the greatest challenge in the production of organic crops [6,7]. This makes additional N input inevitable. Therefore, the search continues for materials which would be used to improve the N content and so enhance the efficiency and quality of composts at low cost. Composts can be enriched with inorganic N fertilizers to ensure complementary manure-chemical fertilizers use or the development of organo-mineral fertilizers [8], microbial inoculum to hasten lignin decomposition [9,10] and biologically-active substances [11]. Thepotentials of agricultural wastes, as organic N sources, for raising the N levels of composts should be exploited.

The cattle industry is a source of wastes- bones, hoofs, blood and horns- which can be used as organic N sources to enrich composts and the efficiencies compared to the leaves of some common plants such as neem (*Azadirachta indica* L.) and Mexican sunflower (*Tithonia diversifolia* (Hemsl.) A. Gray). The neem tree is native to India and Burma where it has, for centuries, been revered as the ‘village pharmacy’ because of the various medicinal properties in all parts of the plant. Apart from the promotion of health and the value as a safe control of household and farm pests, the tree is a source of fertilizer as the leaves neutralize soil acidity and provide nutrients and organic matter which increase soil fertility and water holding capacity thereby improving soil health and fostering sustainable crop production [12,13]. The uses include puddling of the leaves and twigs into flooded rice fields before seedlings are transplanted in India [13,14]; as mulch in tobacco fields in Sri Lanka and tomato in Gambia [14] through which plants matured earlier and had more numerous and larger branches. Tithonia is a broadleaf shrub native to Eastern Mexico but now widely distributed throughout the tropics and sub-tropics [15] where it has become a weed problem in crop farms and waste lands. It grows rapidly to form dense large communities within a short time thereby suppressing and eliminating other weeds. Tithonia is used for composting, green manure and mulch while its ability to accumulate large amounts of N, P and K from the soil increases the value as a fertilizer such that application of fresh or ground dried leaves resulted in better okra growth and yield [16].

The cattle abattoir wastes and leaves can be dried, ground into powder (meals) and used as materials to supplement the N content of composts. 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 use incubation studies to assess the N content and rate of release from the enriched composts.

2. MATERIALS AND METHODS

This study was carried out on the Teaching and Research Farm, Ekiti State University, Ado-Ekiti, Nigeria located on latitude 7°31'N and longitude 5°13'E in South-Western Nigeria in the year 2013. Fresh poultry droppings from layers' battery cages, cow dung, cattle abattoir wastes (blood, horns, hoofs, and bones) and sawdust were collected 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, Mg, K and Na by wet digestion using concentrated nitric, perchloric and sulphuric acid mixture in a ratio of 25: 5: 5 respectively; P was determined by vanado-molybdate method, Ca, Na and K determination was by flame photometry while Mg was determined by atomic absorption spectrophotometry [17].

2.1 Composting

Cow dung and sawdust (CDSD), poultry droppings and sawdust (PDSD) 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 Table 1.

Each compost was enriched to 10, 20, 30 and 50 kg N by the addition of the enrichment materials. 45.7 g, 172.6 g, 299.5 g and 553.3 g of blood meal were added respectively to 100kg of the CDSD composts to make up to 10, 20, 30 and 50 kg N while 73.6 g, 200.5 g, 327.4 g and 581.2 g of same blood meal were added respectively to 100 kg of the PDSD composts to make up to 10, 20, 30 and 50 kg N. 1800.0 g, 6800.0 g, 11800.0 g and 21800.0 g of bone meal respectively were added to 100 kg of the CDSD composts to enrich them to 10, 20, 30 and 50 kg N while 2900.0 g, 7900.0 g, 12900.0 g and 22900.0 g of the bone meal respectively were added to 100 kg

Table 1:The treatments used in the study and their description

Treatments	Description
CDSD	Cow dung + sawdust
CDSDBM	Cow dung + sawdust + blood meal
CDSDBN	Cow dung + sawdust + bone meal
CDSDHN	Cow dung + sawdust + horn meal
CDSDHF	Cow dung + sawdust + hoof meal
CDSDTM	Cow dung + sawdust + tithonia leaf meal
CDSDNM	Cow dung + sawdust + neem leaf meal
PDSD	Poultry droppings + sawdust
PDSDBM	Poultry droppings + sawdust + blood meal
PDSDBN	Poultry droppings + sawdust + bone meal
PDSDHN	Poultry droppings + sawdust + horn meal
PDSDHF	Poultry droppings + sawdust + hoof meal
PDSDTM	Poultry droppings + sawdust + tithonia leaf meal
PDSDNM	Poultry droppings + sawdust + neem leaf meal

of PDSD composts to make them up to 10, 20, 30 and 50 kg N. 81.4 g, 307.7 g, 533.9 g and 986.4 g of horn meal respectively were added to 100 kg of CDSD composts to enrich them to 10, 20, 30 and 50 kg N while 131.2 g, 357.5 g, 583.7 g and 1036.2 g of same horn meal respectively were added to 100 kg of PDSD composts to enrich them to 10, 20, 30 and 50 kg N. 62.0 g, 234.0 g, 406 2 g and 750.4 g of hoof meal respectively were added to 100 kg of CDSD composts to enrich to 10, 20, 30 and 50 kg N while 99.8 g, 271 9 g, 444.1 g and 788.3 g of the hoof meal respectively were added to 100 kg of PDSD composts to enrich them to 10, 20, 30 and 50 kg N. 36.5 g, 137.8 g, 239.1 g and 441.7 g of neem meal respectively were added to 100 kg of CDSD composts to make them up to 10, 20, 30 and 50 kg N while 58.8 g, 160.1 g, 261.4 g and 464.0 g of same neem meal were added to 100 kg of PDSD composts to raise the N content to 10, 20, 30 and 50 kg N. 43.9 g, 165.9 g, 287.8 g and 531.7 g of tithonia meal were respectively added to 100 kg of CDSD composts to make them up to 10, 20, 30 and 50 kg N while 70.7 g, 192.7 g, 314.6 g and 558.5 g of same tithonia meal were added to 100 kg of PDSD composts to make them up to 10, 20, 30 and 50 kg N.

2.2 Incubation

Two kilograms (2 kg) of topsoil (Table 3) were weighed into 2.5-litre bowls (and each of the enriched composts, at the rate of 30t/ha was thoroughly mixed with the soil, moistened with an equal amount of water and covered with black polythene sheets and kept in a cool place. Each treatment was replicated four times to accommodate the monitoring of total N contents in samples at 4, 8, 12 and 16 weeks of incubation.

3. RESULTS

Table 2 shows the chemical properties of the composting materials, the enrichment materials, and the compost product. Within the composting materials,PD, CD and SD were alkaline (pH=8.0-8.4). Total N, K and Ca contents were highest in PD; CD contained the highest total P while Mg content varied between 6.0 and 6.7 g/kg in the three composting materials. Within N enrichment materials, BN, HN and TM were alkaline while BM, HF and NM were slightly acidic (pH=6.2-6.5). NM contained the highest N (98.7 gkg^{-1}) while BN contained the least N (2.0 g kg^{-1}). HN and BN had the highest total P (256.3 and 241.4 g kg^{-1} respectively) while the other enrichment materials contained P in the order TM > NM > HF > BM. HF and BM contained the highest Ca; total Mg ranged from 5.8 to 6.6 g kg^{-1}, total K and Na contents from 4.1 to 5.1 g kg^{-1} and from 0.5 to 1.1 g kg^{-1}, respectively, in the enrichment materials. The composts were alkaline; CDSD contained higher total N, Ca, Mg, K and Na values whereas PDSD contained more total P.

In the incubation study, the changes in total N contents of soil that was amended with composts enriched with organic N sources are shown in Figs. 1 and 2. The CDSD control contained 4.7 gkg^{-1} N at week 4 which decreased to 3.6 gkg^{-1} at week 8 and increased to 4.6 and 5.0 g kg^{-1} at week 12 and 16, respectively. These values are higher than the N content of the compost before incubation. The PMSD control decreased from 5.7 g kg^{-1} at week 4 to 4.1 gkg^{-1} at week 8 but increased to 4.9 and 5.7 g kg^{-1} at week 12 and 16, respectively. The values are lower than N content of the compost before incubation. PDSDBM enriched to 50 g kg^{-1} N gave highest values of N at 12 and 16 weeks of incubation.

Table 2. Some chemical properties of the compost materials and the organic N sources used in the study

Parameters	Values								
	Enrichment materials						Composting materials		
	Blood meal	Bone meal	Hoof meal	Horn meal	Tithonia meal	Neem meal	Cow dung	Poultry manure	Saw dust
pH	6.2	10.5	6.2	8.2	8.2	6.5	8.0	8.4	8.4
Total N (gkg^{-1})	78.8	2.0	58.1	44.2	82.0	98.7	53.9	79.2	0.9
Organic C (g kg^{-1})	325.6	7.8	405.4	182.6	339.1	407.8	222.9	327.2	334.3
Total P (g kg^{-1})	3.2	241.4	8.9	256.3	26.8	11.7	268.2	86.4	2.2
Calcium (g kg^{-1})	12.2	10.9	12.1	10.0	9.7	9.2	9.5	13.1	10.4
Magnesium " "	6.1	5.8	6.6	6.0	6.2	5.9	6.0	6.7	6.4
Potassium " "	4.4	4.1	5.0	4.1	5.1	4.1	4.4	5.2	4.8
Sodium " "	1.1	0.8	0.7	0.7	0.5	0.5	0.8	0.8	0.5

The patterns of N content were: (i) consistent increase from 4 to 16 weeks incubation in five (5) treatments (CDSDNM at 10, 20, 50 g kg^{-1}N; PDSDHF at 10 g kg^{-1} N; PDSDBM at 20 g kg^{-1} N) (ii) increase from 4 weeks to the same value at 12 and 16 weeks in one (1) treatment (CDSDNM at 30 g kg^{-1} N) (iii) decrease by average 20% from week 4 to week 8 followed by steady increase at 12 and 16 weeks of incubation in the remaining treatments. CDSDBM, CDSDBN, and CDSDHF at 50 g kg-1 N gave the highest N contents at week 4 while CDSDNM at 50 g kg^{-1} N contained the highest N at 8, 12 and 16 weeks incubation. PDSDBN, PDSDTM at 50 kg^{-1} N contained highest N at 4 and 8 weeks of incubation while N contents obtained in enriched CDSD were in treatments No. eight (8), none (0), one (1) and 16 at 4, 8, 12 and 16 weeks of incubation respectively while 13 treatments contained highest N at week 4; none (0) at weeks 8 and 12; and 12 treatments at week 16 for PDSD (Table 3).

N contents of enriched composts compared to the original composts showed that 26 treatments- 6, 11, 5 and 4 at 4, 8, 12 and 16 weeks of incubation; and 63 treatments- 13, 22, 19 and 9 at 4, 8, 12 and 16 weeks of incubation were deficient based on 42 gkg^{-1} N in CDSD and PDSD at 64 g kg^{-1} N respectively. The enriched composts were also compared to the N contents of the controls at each period of incubation.

The numbers in parentheses are the enrichment levels. They further explain the contents of figures. For example, the last line highlighted in yellow colour means that over the incubation period, CDSDBM and CDSDHM at enrichment level of 30 t ha^{-1} did not show any reasonable difference in N content.

At week 4, N contents exceeded the 47 gkg^{-1} N in the CDSD control in 15 treatments; 20 treatments were greater than 36 g kg^{-1} N at 8 weeks of incubation; 16 treatments contained more N than 46 gkg^{-1} N at week 12; and 15 treatments exceeded the value of 50 gkg^{-1} N at week 16. At 4 weeks of incubation, 17 treatments exceeded 57 g kg^{-1} N in the PDSD control while 22, 21 and 23 treatments contained more N than 41, 49 and 57 g/kg N at 8, 12 and 16 weeks incubation respectively.

4. DISCUSSION

Nutrient depletion would threaten the sustainability of crop production systems especially when crop removal continuously mines soils of nutrients without conscious adequate replenishment. Thus, the need to reverse the negative nutrient budgets of soils in order to maintain productivity, especially in more permanent cropping systems, led to the promotion of chemical fertilizers whose use produced the high crop yields that characterized the green revolution. Unfortunately, the fertilizers have become too expensive and difficult to obtain for the subsistence farmers on account of scarcity and which make the use uneconomical [18]. Soil application of wastes, especially those generated in animal industries, is a means of disposal but the local availability of several organic materials for composting has made composts popular and accepted as the preferred alternative sources of nutrients. Thus, the preparation of composts from cheap organic materials and use in crop production systems are strengthened by the ability to maintain soil fertility and dispose livestock industry wastes which would otherwise constitute environmental pollution threats [19]. At 22 weeks, the composts have dark brown/black colour indicating that they were matured and ready for use [20]. Composting decreased the C/N ratio, increased the pH and the exchange capacity of the product because the breakdown of organic compounds in plant matter and animal wastes by bacteria and fungi hardly reduced the concentrations of Ca, Mg and K which are mainly responsible for basic or alkaline reactions [21]. The N contents of the composts (42 and 64 g kg^{-1}) were similar to average 50 g kg^{-1} contained in well-decomposed farmyard manure but low compared to manures from sheep and goats (300 g kg^{-1}), cattle (97 gkg^{-1}) and poultry (120-303 gkg^{-1}) [22,23]. This can be attributed to the dilution by sawdust which has high lignin content and C: N ratio [24]. It had been observed that N concentration in organic materials determines the net balance between mineralization and immobilization and in materials with N concentration below 24 g kg^{-1} N, such as sawdust used for composting, immobilization will exceed mineralization and the decomposing organic material will tie up N [25]. However, the same would not explain the very low total P contents of the composts compared to the values obtained in the poultry droppings and cow dung used as composting materials. This is because although N and P are needed for the rapid growth and multiplication of microbial populations involved in organic matter decomposition, the processes would hardly engender such substantial losses of P.

The patterns in N contents over the periods of incubation would probably indicate the best time to use the composts. Enriched CDSD and PDSD had 46% of the treatments with the highest N contents at 4 weeks of incubation and a decrease till week 16; 26% showed increase at week 8 followed by a decrease till week 16 while equal proportion (16%) of the treatments showed increase till week 12 followed by decrease at week 16 and increase from week 4 till highest N content at week 16. The highest N contents at 4 and 8 weeks of incubation imply that the enriched composts would be suitable for the production of short-season crops such as leaf vegetables (leaf amaranth, *Corchorus olitorius*, *Celosia argentea*, *Talinum fruticosum* etc) while those with highest values at 12 and 16 weeks of incubation will support the growth needed for optimum yield of long-duration leaf and fruit vegetables such as okra, tomato, sweet corn, eggplant, egusi (*Citrulluslanatus*), worowo (*Senecio biafrae*), fluted pumpkin (*Telfairia occidentalis*) etc.

The lower N content in most treatments at 8 weeks indicates immobilization which could be the lower N content in most treatments at 8 weeks indicates immobilization which could be due to N fixation in response to the increase in microbial population [26,27]. The trend in N content would also be due to the factors that determine the rate of decomposition of the composts and enrichment materials which include the quality of the material especially the N and carbon contents [28]. The carbon quality of the organic material applied, as indicated by the C: N ratios would determine the nature and extent of N mineralization in the soil [29,30,31].

CDSDNM at all levels of N enrichment continued to increase in N content which probably meant reduction in the fixation of available N. This performance could be linked to the higher N content of the neem meal, lower C: N ratio of the CDSD than PMSD which is an indication that N would be released earlier and faster in CDSD [32]. Besides, neem products (seeds, seed oil and extracts) are used to retard nitrification of N fertilizers in soils and so resulted in substantial increase in N use efficiency in crops [33]. PDSDBN and PDSDTM at 50 g kg^{-1} N with highest N contents at 4 and 8 weeks incubation would be suitable for short-season vegetables while PDSDBM at 50 g kg^{-1} N which had highest N at 12 and 16 weeks incubation would be recommended for long-season tropical leaf and fruit vegetables.

Table 3. Patterns of N contents in composts enriched with organic N sources as influenced by periods of incubation

Patterns of N contents	CDSD Composts	PDSD Composts
Highest at week 4, decrease till week 16	**CDSDBM (10, 20)**	**PDSDBM (20)**
	CDSDBN (10)	PDSDBN (20, 30, 50)
	CDSDHN (30,50)	PDSDHN (30)
	CDSDHM (20,50)	PDSDHM (50)
	CDSDNM (20,50)	PDSDNM (10, 20, 50)
	CDSDTM (10)	PDSDTM (30, 50)
Increase at week 8, decrease till week 16	CDSDBM (50)	PDSDBM (50)
	-	PDSDBN (10)
	-	PDSDHM (20)
	-	PDSDNM (30)
	CDSDTM (30)	PDSDNM (30)
Increase to week 12 followed by decrease	**-**	PDSDBM (10)
	CDSDHN (20)	PDSDHN (20)
	CDSDTM (20, 50)	**-**
Increase from week 4 till week 16	**-**	PDSDBM (30)
	CDSDBN (20, 30, 50)	**-**
	CDSDHN (10)	PDSDHN (10, 50)
	CDSDHM (10)	PDSDHM (10, 30)
	CDSDNM (30, 50)	-
No difference over incubation time	CDSDBM (30)	**-**
	CDSDHM (30)	**-**

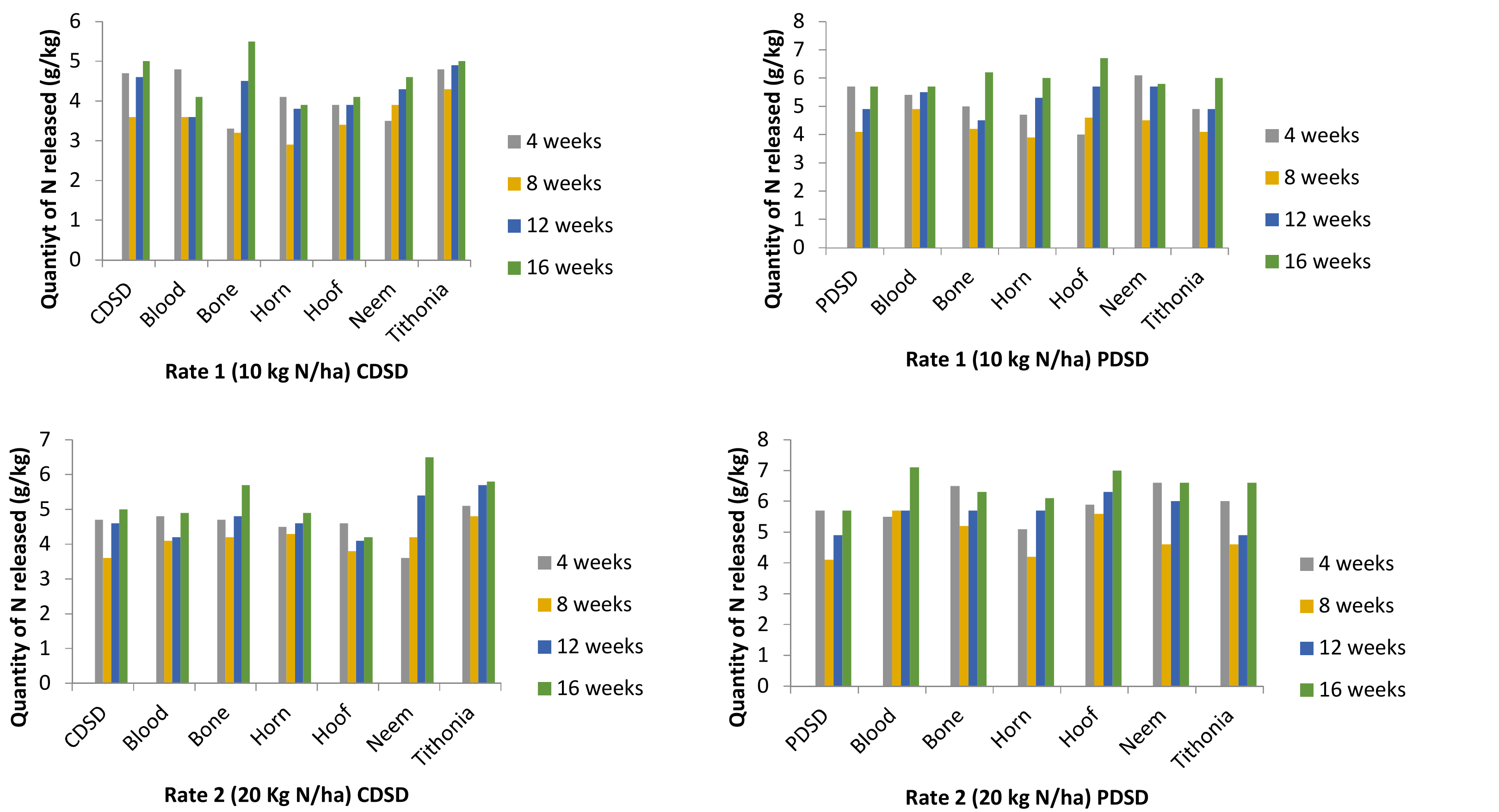

Fig. 1. Quantity of N released during incubation for rate 1 (10 kg N/ha) and rate 2 (20 kg N/ha)

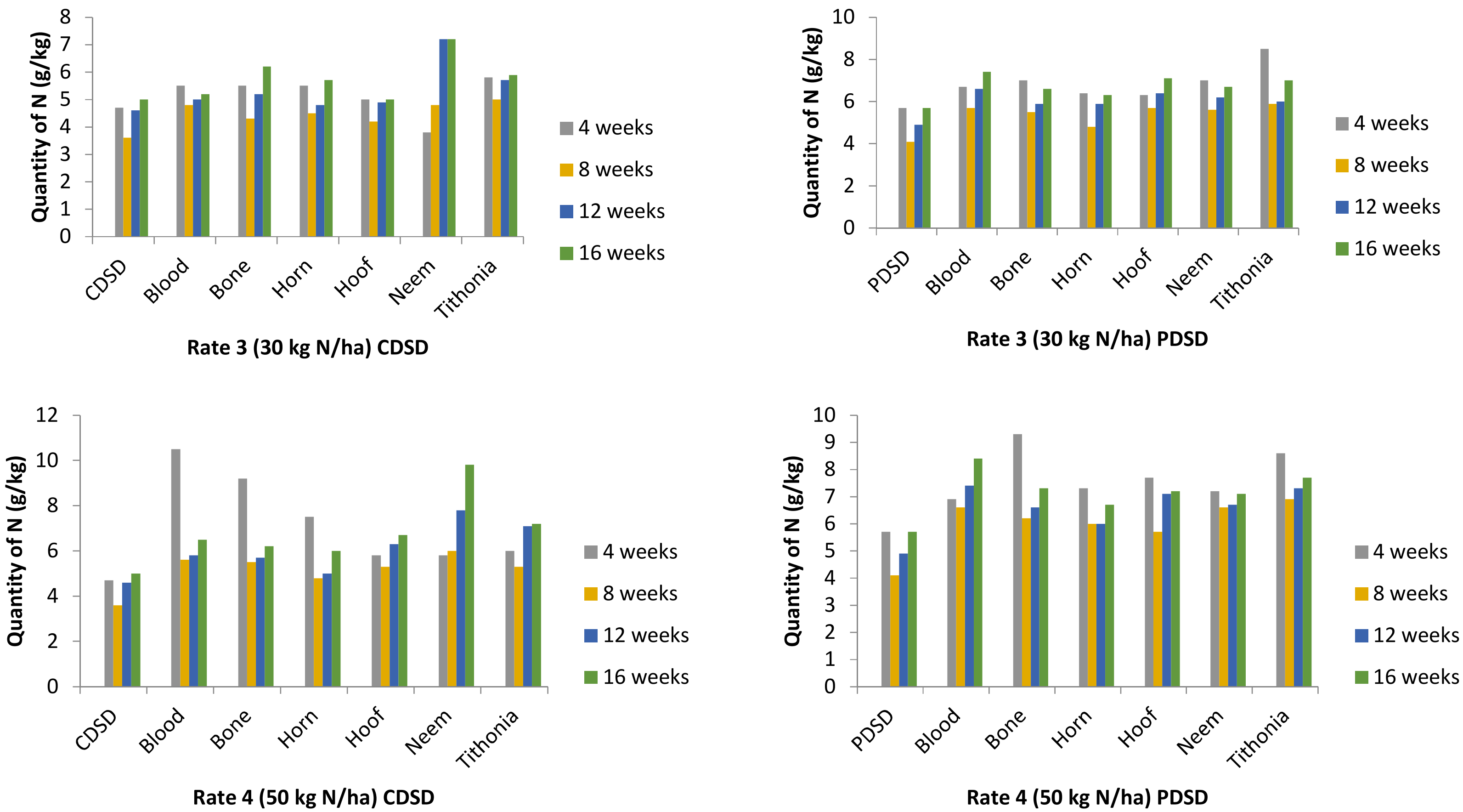

Fig. 2. Quantity of N released during incubation for rate 3 (30 kg N/ha) and rate 4 (50 kg N/ha)

The application of organic materials to enrich composts at 50 g kg^{-1} N gave the highest N contents over the incubation period. However, the level of N should be increased in order to produce value-added composts that can be added at substantially low rates of few $kgha^{-1}$ compared to conventional manures and composts added at 10-30 t ha^{-1} [34]. The choice of 16 weeks incubation is based on the longest period most arable crops stay on the field and the high N contents will support the growth of the crops.

5. CONCLUSION

An additional input of N is inevitable to ensure that the N level in composts would support crop performance. Therefore, the need to identify the organic materials which would improve the N contents of composts at least cost has become more urgent. Studies were conducted in two phases to: (i) determine the nutrient compositions of the agricultural wastes used for composting and as organic N sources; and (ii) assess the N content of the composts during 16 weeks of incubation. The N contents of the composts produced at 22 weeks were enriched with organic nitrogen sources, like blood, bone, horn, hoof meals, neem leaf and tithonia leaf meals to rates of 10, 20, 30, 40, 50 g kg^{-1} N equivalent. The N release patterns of the enriched composts and controls were monitored as total N contents at 4, 8, 12 and 16 weeks of incubation. The pattern of N content indicated initial N immobilization in all the composts at 8 weeks of incubation followed by higher values at 12 and 16 weeks of incubation. The highest N contents were recorded from all the organic materials at 50 g kg^{-1} N enrichment. The N content of CDSDNM increased at all levels of enrichment over the period of incubation to the highest values at 50 g kg^{-1} N. PDSDBN and PDSDTM at 50 g kg^{-1} N had the highest N contents at 4 and 8 weeks incubation and would be suitable for short-season crops while PDSDBM at 50 g kg^{-1} N with the highest N at 12 and 16 weeks incubation would be recommended for long-season crops, especially leaf and fruit vegetables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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