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Characterization of Biochar and Compost Produced from different Plant Materials and Its Swine-based Compost for Soil Nutrient Release

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ABSTRACT: *This study focused on potential of different plant materials to release nutrients, its transformation into biochar and compost, and effect of this transformation on some chemical properties in relation to bioavailability of end-products. Preparations of Compost and Biochar were carried out by Aerobic Heap and Top-lit Up-Draft kiln methods respectively for six different plant materials (Cassava peels, Gliricidia cuttings, Maize stovers, Neem clippings, Panicum maximum and sawdust). Chemical analysis was carried out, before and after transformation. Wide variability in the capacity to release nutrients was discovered from analysis of the initial plant materials. The degree of abundance of nutrients (macro and secondary elements) in either compost or biochar, produced from different plant materials was observed. However, the most significant build of these nutrients was observed in Gliricidia-Swine based compost. Therefore, depending on duration of the crop, either biochar or compost will be a suitable soil amendment for soil fertility management.*

KEYWORDS: soil nutrient management, plant materials, chemical properties, bioavailability, compost, biochar.

INTRODUCTION

Practices that will improve the protection of the environment and natural agricultural resources necessary to ensure the production of adequate and high quality foodstuffs at affordable costs which the rapidly growing world population needs, is key to sustainable agriculture and particularly, crop production (Muhie, 2022). Soil fertility decline and nutrient stress are major natural constraints to food and crop production in the tropics (Wawire *et al*., 2021). Soil fertility is fundamental to agricultural productivity and, subsequently, global food security. However, conventional agricultural practices have often resulted in soil degradation, nutrient depletion, and reduced soil health (Lal, 2020). Strategies to mitigate this constraint have to do with the soil fertility management. Soil fertility management practices, such as biochar, and compost application have been used to maintain soil structure, sequester carbon, reduce nutrient leaching and erosion, alleviate soil compaction and improve beneficial soil microbial community (Dincă *et al*., 2022). These microorganisms are the basis for enhancing soil fertility and ensuring sustainable agriculture.

Importantly, biochar's porous nature and high surface area enable it to adsorb and retain nutrients, potentially enhancing their availability to plants (Lehmann *et al*., 2003). This characteristic makes biochar a particularly attractive amendment for improving nutrient use efficiency in agricultural systems (Biederman and Harpole, 2013). Use of this organic material is a major sustainer of the soil organic matter, which holds the soil nutrients. Despite the growing interest in biochar, its effects on soil nutrient dynamics, particularly nitrogen (N), phosphorus (P), and potassium (K), are not fully understood (Agegnehu *et al*., 2017). These macronutrients are crucial for plant growth and productivity, and their availability can significantly influence crop yields (Marschner, 2012). Nitrogen is a vital component of amino acids and proteins, phosphorus is essential for energy transfer and genetic material, and potassium plays a key role in enzyme activation and osmoregulation (Havlin *et al*., 2014). Therefore, understanding how biochar influences the availability of these nutrients is critical for optimizing its use in agricultural practices. Compost is an organic matter that has been decomposed and recycled as a fertilizer and soil amendment. Compost use is one of the most important factors, which contribute to increased productivity and sustainable agriculture. Swine manure contains essential plant nutrients and has been reported to be effective in increasing yields of cereals, legumes, vegetables and pastures as well as in increasing plant nutrient concentration especially N, P and K (Choudhary et al. 1996).

The agricultural utilization of transformed waste plant materials as either biochar or compost implies knowing its degree of nutrient bioavailability, as well as its content and bio-geochemical forms present. The transformations used in conversion either by charring or composting leads to further development of microbial populations, which cause numerous physio-chemical changes within the medium. These changes could influence the nutrient distribution through release during organic matter mineralization or the elemental nutrient solubilization through decrease of pH (Ouédraogo *et al.*, 2001).

Biochar and compost are a reservoir of nutrients that can be released to the soil. This aims to optimize the condition of the soil, with regard to its physical, chemical, biological and hydrological properties, for the purpose of enhancing farm yield. These soil amendments/fertilizers are needed for high yield, particularly in nutrient-poor soil and are considered an economic and environmental friendly alternative (Khurshid *et al*., 2006). The aim of this study therefore, is to evaluate compost and biochar produced from different plant materials, and swine waste for its nutrient releasing potential, the effect on ionic interaction as well as the abundance of its availability.

MATERIALS AND METHODS

Description of experimental site

The study was conducted at the Institute of Agricultural Research and Training (I.A.R&T), Moor Plantation in Ibadan, Oyo State located in the south western part of Nigeria (West Africa) between N 7^o 376605 – 7^o 377182; E 3^o 841198 – 3^o 84212, and 144 – 149 m above mean sea level.

Description of the plant materials used for biochar and compost preparation

The enrichment (animal waste) source used in the composting was swine dung, which was collected from IART Piggery farm. The carbon (plant materials) source used includes: Cassava (*Manihoti esculentus*) peels, *Gliricidia sepium* cuttings, Neem (*Azadirecta indica*) clippings, Guinea grass (*Panicum maximum*) cuttings, maize (*Zea mays*) stover, and sawdust (Mahogany).
These were subjected to phyto-sanitation procedures by air-drying for seven days. After 7 days of dry treatments, the plant materials (carbon sources) were chopped into small sizes (5.0 cm) using machetes for both carbonizing and composting respectively.

Biochar preparation

In this study, three types of plant biomass were selected based on their agricultural significance, nutrient content, and availability: Woody biomass (from Neem clippings, Gliricidia cuttings and Sawdust), Agricultural residues (Cassava peels and Maize stovers), and Grasses (*P. maximum*). These represent a diverse range of biomass types, each characterized by different chemical compositions, including varying levels of carbon, nitrogen, and other essential nutrients (Jindo *et al*., 2014).

The biomass materials were collected from local agricultural sources to ensure uniformity, fresh material origin, quality and representative samples. The collected biomass was first air-dried for several days to reduce moisture content to below 10 %, which is crucial for efficient pyrolysis (Schmidt and Taylor, 2014). Once adequately dried, the materials were shredded into smaller pieces (approximately 1–2 cm) using a mechanical shredder to increase surface area for more efficient charring during the pyrolysis process (Spokas *et al*., 2012).

The pyrolysis process was conducted using a stove/kiln pyrolysis reactor (Top-lit Up-Draft mode) under carefully controlled conditions (Cornelissen *et al*., 2016). The pyrolyzer consists of combustion chamber where biomass is placed, and an external source of ignition starts the process. The device is designed to maintain optimal temperatures (between 300°C and 650°C) required for effective pyrolysis (Graber *et al*., 2010), based on previous studies showing that biochar properties such as surface area, porosity, and nutrient retention differ significantly across this temperature range (Enders *et al*., 2012). Each biomass type was subjected to the same pyrolysis conditions to standardize the procedure and enable comparative analysis of the resulting biochars. The products were milled to fine powder using a mechanical grinder.

Compost preparation

The heap ($1.0 \times 1.0 \times 1.0\ m^3$) aerobic method was used for composting on a clean ground surface and covered with white polyethylene. Six heaps are containing 24 kg of swine dung and 12 kg of different carbon (plant materials) sources each representing 66.7 and 33.3 % of enrichment and carbon respectively. The composting pits were filled with shredded plant materials and enrichments in layers. In brief, bottom of each pit was filled with different plant materials as predetermined. Subsequent layer had the swine dung (enrichment) spread onto the previous layer.

The different combinations of pre-determined shredded plant materials composted with swine dung on dry weight basis were: (A). Cassava peel (12 kg) /swine dung (24 kg); (B). Sawdust (12 kg) /swine dung (24 kg); (C). Maize Stover (12 kg) /swine dung (24 kg); (D). Neem clippings (12 kg) /swine dung (24 kg); (E). *Panicum maximum* cuttings (12 kg)/swine dung (12 kg); (F). *Gliricidia sepium* cuttings (12 kg) /swine dung (24 kg). Thus, each shredded plant materials were combined with swine dung at ratio 1:2 mass of materials (C: N).

The properties of different plant materials and swine dung used are presented in Table 1. Moisture content of the composting mixtures was adjusted to 40 % by weight with the addition of tap water. The composting period was 60 days. At maturity, the compost was air—dried on clean polythene sheets under shed.

Characterization of the plant materials /carbon sources, biochar and matured compost

Three sub-samples each of enrichment/manure, various carbon/plant sources, biochar, and matured compost, were taken and analyzed for total N, P, K, organic carbon (Bationo *et al*., 2007), organic matter (OM), Ca, Mg, ash and moisture contents. Organic carbon was determined using the Walkley–Black method (Nelson and Sommers, 1973), total nitrogen by the Kjeldahl digestion and distillation procedure as described in Soil Laboratory Staff (1984). Phosphorus and potassium were determined after ashing 0.5 g sample in a muffle furnace at a temperature of 450–500 °C for 4 hours. For phosphorus, the ammonium molybdate method using a spectrophotometer was used. Potassium in the ash was determined using the Gallenkamp flame analyzer. Calcium and magnesium were determined by EDTA titration using the procedure of Anderson and Ingram (1998). The following nutrient ratios Ca/Mg, K/Mg, C/N and Ca/K were calculated.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using GenSat Discovery Edition 4.10.3D E-statistical software, and where the F-value was significant, treatment means were separated at $P \leq 0.05$ level of significance using Duncan multiple range test (DMRT) (GenSat, 2011).

RESULTS

Nutrient variability of the different feedstock before transformation to biochar and compost

The nutrient concentration of the feedstock used for the conversions, to compost and biochar as shown in Table 1, is an indication of the variability that was observed in the materials used. Cassava peel had the highest ash content with the lowest value obtained from Gliricidia cuttings.

The moisture content ranged between 3.38% and 6.77%, with Gliricidia with the lowest value and with comparative values for cassava peels and saw dust. The percentage of organic C and invariably organic matter ranged between 0.11 and 1.69%, with cassava peels having the highest value while saw dust had the lowest value. The total N, P and K content of the feedstock was initially not high but notable was the percentage Ca content in the materials evaluated. The C: N ration varied from 12:1 to 0.6:1, with the lowest value obtained for saw dust. Interactions between some ions were carried out, to study possible antagonistic reactions as result of using this feedstock.

Nutrient Composition of biochar produced from different feedstock

A reduction in the total ash content was observed after the transformation of the different feedstock to biochar (Table 2). The moisture content also reduced, ranging between 1.28% and 2.62%. There was however a buildup of organic C and invariably organic matter, with a range between 1.26 and 8.79 (organic matter). There was slight increase in total N as a result of some of the feedstock used while a decrease was observed in others. A similar trend was observed for total P and K. A significant buildup of Ca was observed for saw dust based biochar, as compared to other types of biochar produced. An increase in the carbon to nitrogen ratio was observed, especially for 4 out of the 6 biochar produced.

Exceptions were observed for maize and saw dust based biochar. Significant differences were also observed for other interactions calculated.

Nutrient Composition of compost produced from different plant materials and with swine waste

An increase in the total ash content was observed after transformation of the plant materials with swine waste to compost (Table 3). Higher moisture content was observed as compared to different biochar produced. A higher organic carbon content was also observed as compared to what was observed after transformation to biochar Gliricidia based compost had the highest value while the least value was observed for the saw dust based compost. The total nitrogen content of the matured compost also increased, in comparison to what was observed for the different biochar produced.

Gliricidia based compost also had the highest total N content while the least value was obtained for saw dust based compost. There was no significant increase in the values obtained for phosphorus and potassium. However, notable was the increases observed for calcium, with the maize based compost having the highest value. Lower values were observed for the C: N ratio as well as other interactions.

Abundance of nutrients before and after transformation to biochar and compost

Variability was observed in the abundance of nutrients characterized before and after transformation (Table 4). Before the transformation of the feedstock analyzed, cassava peels had most of the nutrients in abundance, followed by Gliricidia. After transformation to biochar and compost, Gliricidia had the highest abundance of nutrients as compared to other types of biochar and compost produced.

DISCUSSION

There was variability in the nutrient concentrations as observed in the different plant materials evaluated, signifying a wide range of alternatives to inorganic fertilizer and most especially for choice of an effective plant material for subsequent transformation to either biochar or compost.

The characteristics of biochars and composts have been discussed to be influenced by the chemical composition of the plant materials (Ndoung *et al*., 2021; Fernandez *et al*., 2021). The moisture content of the composts produced were within the optimum range and so cured while Gliricidia had the highest ash content and therefore has the highest ability to supply soil nutrients.

Initially, cassava peels with the highest value for carbon, showed the ability to give more stability to nutrients being released than the other plant materials. Generally, all the plant materials evaluated had

Ca in greater quantities and therefore exhibits a liming potential. The C:N ratio observed shows the ability of most of the plant materials evaluated to result to mineralization and not immobilization of nutrients.

There was a reduction in the total ash content after transformation to biochar as compared to compost, signifying that compost will have a greater potential to release more nutrients, over time. Although there was a buildup of carbon after transformation to biochar, the values obtained for compost was higher. Compost has been reported to have the highest soil carbon sequestration potential (Biala, 2011). However, biochar has also been identified as carbonized biomass and has been found to be able to sequestrate carbon (Lehmann *et al*., 2006). Gliricidia showed the highest potential, for the buildup of carbon either with biochar or compost. Gliricidia has been reported to have a potential for both short and long term buildup of carbon (Coser *et al*., 2018). There were slight increases in the macronutrients determined, either with transformation to biochar or compost. However, total N increased as compared to the initial values with the transformation of the feedstock to compost and the highest value was obtained with Gliricidia based compost. Gliricidia is a leguminous tree and so the ability to fix nitrogen is being exhibited (Figueiredo *et al*., 2023). Calcium increased after the two transformations but with the highest value obtained with biochar, signifying the higher ability of biochar to act as a liming agent. The carbon to nitrogen ratio for biochar increased after the transformation while there was a decrease for compost, signifying a greater ability of biochar to mineralize soil nutrients quickly as compared to compost. A general overview of the availability of soil nutrients after the two transformation processes, shows gliricidia with the largest abundance of nutrients and therefore a more effective source of soil nutrients as biochar or compost.

Implication to Research and Practice

Biochar and compost has distinct but complementary impacts on soil properties, making their applications particularly effective in enhancing soil fertility, structure, and biological activity. Biochar, due to its high porosity and surface area, improves soil aeration and water retention (Kumar *et al*., 2020). Compost, on the other hand, supplies nutrients in a slow-release form, adds organic matter and nutrients directly to the soil, fostering microbial activity and nutrient cycling (Agegnehu *et al*., 2017) which can complement biochar’s nutrient-holding capacity. For instance, biochar from woody biomass could be applied in soils requiring structural improvement due to the possession of higher carbon stability (Biederman and Harpole, 2013), while biochar from grasses or agricultural residues could be selected in soils needing nutrient improvement for additional nutrients (N and P) that can enhanced soil fertility directly (Cornelissen *et al*., 2013). Here, the combinations of biochar and compost can further synergize these benefits.

CONCLUSION

Comparing compost and biochar as related to the initial plant material is a good way of determining which material is suitable for these transformations and which transformed material will be effective for specific soil nutrients supply. In this study, it has been discovered that there is a wide variability in nutrients availability in different plant materials. Also, the potential of either compost or biochar has been identified especially for the buildup of carbon, which is a building block for soil nutrients. There was however more nutrient release in the composts produced as compared with biochar, with the Gliricidia- swine compost having more of the nutrients determined.

Future Research

Future research on Biochar and Compost derived from different biomass and to be used as soil amendments should focus on understanding the relationships between the biomass material types, soil characteristics specification, and crop-specific responses to optimize their use for sustainable agriculture. These efforts will help address the global challenges of food security, soil degradation, and climate change mitigation.

REFERENCE

Agegnehu, G., Bass, A. M., Nelson, P. N., Muirhead, B., Wright, G., and Bird, M. I. (2017) Biochar and biochar-compost as soil amendments: effects on peanut yield, soil properties and greenhouse gas emissions in tropical North Queensland, Australia. *Agriculture, Ecosystems and Environment*, 233 81-92.

Bationo A., Kihara J., Vanlauwe B., Waswa B., Kimetu, J. (2007) Soil organic carbon dynamics, functions and management in West African agro-ecosystems. *Agricultural System*, 94(1) 13–25

Biala J. (2011) The benefits of using compost for mitigating climate change. The Organic Force. Department of Environment. Climate Change and Water. NSW, Sydney South.

Biederman, L. A., and Harpole, W. S. (2013) Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis. *GCB Bioenergy*, 5(2) 202-214.

Cornelissen, G., Rutherford, D. W., Arp, H. P. H., Duranceau, S., and Thompson, M. (2016) Uplift draft pyrolyzer: Application and development in small-scale, sustainable biochar production. *Biomass and Bioenergy*, 85 1-7.

Cornelissen, G., Rutherford, D. W., Arp, H. P. H., and Thompson, M. (2013) Sorption of pure N_2O, CO_2, and CH_4 to biochars after oxidative treatment: Implications for biochar aging and soil greenhouse gas mitigation. *Journal of Environmental Quality*, 42(1) 232-238.

Coser T.R., Figueiredo C.C.d., Jovanovich B., Moreira T.N., Leite G.G., and Filho S.L.S.C. (2018) Short-term buildup of carbon from low-productivity pastureland to an agrisilviculture system in the Brazilian savannah. *Agricultural Systems*, 166 184-195.

Dincă L.C., Grenni P., Onet C., and Onet A. (2022) Soil Microbial Community: A Review. *Applied Sciences*, *12* (3) 1198, https://doi.org/10.3390/app12031198.

Enders, A., Hanley, K., Whitman, T., Joseph, S., and Lehmann, J. (2012) Characterization of biochars to evaluate recalcitrance and agronomic performance. *Bioresource Technology*, 114 644-653.

Fernandez J.A., Hernandez-Lara, A., Moral R., Perez-Murcia M.D., Bustamante M.A, and Egea-Gilabert C. (2021) Influence of the starting feedstock materials to obtain Compost-Deeping on microbiological characteristics and the relationship with chemical composition. *Acta Horticulturae*, 1317 255-262. Doi:10.17660/ActaHortic:2021.1317.29.

Figueiredo C.C.d., Moreira T.N. Coser T.R., Silva L.P.d., Leite G.G, and De Carvalho A.M. (2023) Nitrogen use efficiency in an Agrisilviculture System with Gliricidia septum in the Cerrado Region. *Plants*, 1647. doi.org/10.3390/plants12081647.

GenSat (2011) GenSat Discovery Edition 4, Release 10.3DE (PC/Windows 7). Hempstead, UK: VSN International Ltd., Roth Amsted Experimental Station, Hameln.

Graber, E. R., Meller-Harel, Y., Kolton, M., Cytryn, E., Silber, A., Rav David, D., and Elad, Y. (2010) Biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media. *Plant and Soil*, 337(1) 481-496.

Havlin, J. L., Tisdale, S. L., Nelson, W. L., and Beaton, J. D. (2014) Soil Fertility and Fertilizers. Pearson.

Kameyama, K., Miyamoto, T., Shiono, T., and Shinogi, Y. (2010) Influence of sugarcane bagasse-derived biochar application on nitrate leaching in calcaric dark red soil. *Journal of Environmental Quality*, 39(5) 1681-1687.

Kumar, R., Kaushal, R., Dhyani, S. K., Alam, N. M., Alam, N. V., and Thakur, V. (2020) Biochar amendments and its implications for soil health, carbon sequestration, and sustainable agriculture. *Agriculture*, 10(8) 337-348.

Jindo, K., Mizumoto, H., Sawada, Y., Sanchez-Monedero, M. A., and Sonoki, T. (2014) Physical and chemical characterization of biochars derived from different agricultural residues. *Biogeosciences*, 11(23) 6613-6621.

Lal, R. (2020) Soil degradation as a reason for inadequate human nutrition. *Food Security*, 12(5) 889-897.

Lehmann J., Gaunt J., Rendon M. (2006) Biochar sequestration in terrestrial ecosystems- a review. *Mitigating and Adaptive Strategy for Global Change*, 11 403-427. doi.10.1007/s11027 005-9006-5.

Lehmann, J., Gaunt, J., and Rondon, M. (2003) Bio-char sequestration in terrestrial ecosystems–a review. *Mitigation and Adaptation Strategies for Global Change*, 11(2) 395-419.

Marschner, H. (2012) Marschner's Mineral Nutrition of Higher Plants. Academic Press.

Muhie S.H. (2022) Novel approaches and practices to sustainable agriculture. *Journal of Agriculture and Food Research*, 10 100446.

Ndoung O. C. N., Figueiredo C.C., and Ramos M. L. G. (2021): A scoping reviews on biochar fertilizers: enrichment techniques and agro-environmental application. *Heliyon*, 7 e08473.

Nelson D., and Sommers L. (1973) Determination of total nitrogen in plant material. *Agronomy Journal*, 65(1) 109–112

Ouédraogo E, Mando A, and Zombre N.P. (2001) Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. *Agriculture Ecosystems and Environment,* 84 259-266.

Schmidt, H. P., and Taylor, P. (2014) The Uplift biochar stove; A clean, low-cost tool for biochar production. *Biochar Journal,* 3(2) 11-14.

Soil Laboratory Staff. (1984) Analytical methods of the service Laboratory for soil, plant and water analysis. Part I: Methods for soil analysis. Royal Tropical Institute, Amsterdam.

Spokas, K. A., Novak, J. M., Venterea, R. T., and Baker, J. M. (2012) Biochar's role as an alternative N-fertilizer: ammonia capture. *Plant and Soil,* 350(1) 35-42.

Wawire A, W, Csorba A, Tóth J.A, Micheli E, Szalai M, Mutuma E, and Kovacs E. (2021) Soil fertility management among smallholder farmers in Mount Kenya East region. *Heliyon,* 7(3) e0648.

Table 1: Physical and chemical properties of different plant materials, and swine dung before transformation as Biochar and Compost

Feedstock	Ash Content	Moisture Content	OC	OM	Total N	P	K	Na	Ca	Mg	C:N	Ca: Mg	Ca: K	K: Mg
	←				%					→				
Cassava peel	8.93^{a}	6.77^{a}	1.65^{a}	2.81^{a}	0.14^{c}	0.11^{a}	1.00^{b}	0.20^{b}	2.07^{ab}	0.50^{d}	20.0^{b}	4.0^{a}	2.0^{b}	2.0^{a}
Gliricidia cuttings	3.30^{c}	3.38^{b}	1.29^{bc}	2.22^{b}	0.28^{a}	0.12^{a}	1.97^{a}	0.28^{a}	2.92^{a}	0.85^{a}	5.0^{c}	3.0^{a}	2.0^{b}	2.0^{a}
Neem clipping	5.85^{a}	5.90^{ab}	1.42^{b}	2.44^{b}	0.21^{b}	0.11^{a}	0.36^{c}	0.22^{b}	1.85^{b}	0.76^{ab}	7.0^{c}	3.0^{a}	5.0^{a}	1.0^{a}
Panicum cuttings	6.79^{b}	4.14^{ab}	0.91^{c}	1.71^{d}	0.13^{c}	0.10^{ab}	1.13^{b}	0.17^{b}	1.74^{c}	0.65^{c}	7.0^{c}	3.0^{a}	2.0^{b}	2.0^{a}
Maize Stover	3.38^{c}	3.48^{b}	0.99^{bc}	1.89^{c}	0.17^{c}	0.11^{a}	0.34^{c}	0.19^{b}	1.85^{b}	0.66^{c}	6.0^{c}	3.0^{a}	5.0^{a}	1.0^{a}
Sawdust	5.45^{b}	6.77^{a}	0.11^{d}	1.58c	0.19^{bc}	0.09^{b}	0.27^{d}	0.17^{b}	1.74^{c}	0.78^{ab}	52.0^{a}	2.0^{ab}	7.0^{a}	0.40^{ab}
Swine dung	5.97^{b}	6.42^{a}	NA	NA	0.15^{c}	0.10^{ab}	0.25^{d}	0.13^{bc}	1.51^{d}	0.76^{ab}	NA	2.0^{ab}	6.0^{a}	0.30^{ab}

Note: Means of feedstocks on rate with same letter within column are not significantly different by DMRT $P < 0.05$.

Table 2: Characterization of Biochar from different plant materials for soil nutrient release

Feedstock	Total Ash	Moisture Content	OC	OM	Total N	P	K	Na	Ca	Mg	C:N	Ca:Mg	Ca :K	K:Mg
	←				%					→				
Cassava peel	3.76^{b}	2.33^{b}	4.03^{c}	6.95^{b}	0.22^{a}	0.92^{a}	0.30^{a}	0.08^{b}	2.15^{b}	0.80^{b}	18^{d}	3^{b}	7^{b}	0.4^{a}
Gliricidia	2.20^{c}	2.75^{b}	5.10^{a}	8.79^{a}	0.15^{b}	0.06^{c}	0.10^{c}	0.05^{c}	0.40^{c}	0.20^{c}	34^{b}	2^{b}	4^{bc}	0.5a
Neem clipping	3.23^{b}	1.28^{c}	4.57^{b}	7.88^{b}	0.20^{ab}	0.88^{a}	0.20^{abc}	0.10^{a}	0.80^{c}	0.65^{b}	23^{c}	1^{b}	4^{bc}	0.3^{a}
Panicum Maximum	5.57^{a}	1.99^{bc}	3.61^{d}	6.22^{c}	0.21^{a}	0.56^{b}	0.30^{a}	0.07^{bc}	2.55^{b}	1.20^{a}	45^{a}	2^{b}	9^{b}	0.3^{a}

Maize Stover	2.49^{bc}	2.62^{b}	1.09^{e}	1.88^{d}	0.23^{a}	0.58^{b}	0.25^{ab}	0.07^{bc}	1.85^{b}	1.30^{a}	5^{e}	1^{b}	7^{b}	0.2^{ab}
Sawdust	3.55^{b}	1.81^{bc}	0.73^{f}	1.26^{e}	0.20^{ab}	0.20^{c}	0.15^{bc}	0.07^{bc}	4.00^{a}	0.80^{b}	18^{d}	5^{a}	27^{a}	0.2^{ab}

Note: Means of feedstocks on rate with same letter within column are not significantly different by DMRT $P < 0.05$.

Table 3: Characterization of Compost made from different plant materials and its swine dung for soil nutrient release

Feedstock	Total Ash	Moisture Content	OC	OM	Total N	P	K	Na	Ca	Mg	C:N	Ca:Mg	Ca:K	K:Mg
	←				%					→				
Cassava peel	4.76^{b}	12.51^{a}	4.84^{c}	8.34^{c}	2.34^{b}	0.17^{b}	0.16^{c}	0.11^{b}	1.59^{b}	0.79^{b}	21^{a}	2^{a}	10^{a}	0.2^{b}
Gliricidia	3.31^{b}	12.39^{ab}	9.67^{a}	16.7^{a}	4.68^{a}	0.22^{a}	0.34^{b}	0.13^{ab}	1.86^{b}	0.56^{c}	5^{b}	3^{a}	5^{b}	0.6^{ab}
Neem clipping	7.23^{a}	12.74^{a}	6.16^{b}	10.6^{b}	2.99^{b}	0.19^{ab}	0.45^{ab}	0.14^{a}	2.63^{a}	1.08^{a}	7^{b}	2^{a}	6^{b}	0.4^{b}
Panicum Maximum	8.17^{a}	12.57^{a}	4.65^{c}	8.01^{c}	2.25^{b}	0.17^{b}	0.44^{ab}	0.16^{a}	1.40^{b}	0.43^{c}	7^{b}	3^{a}	3^{c}	1.0^{a}
Maize Stover	6.39^{ab}	12.19^{b}	5.31^{c}	9.15^{c}	2.57^{b}	0.20^{ab}	0.64^{a}	0.09^{b}	2.77^{a}	0.98^{a}	6^{b}	3^{a}	4^{bc}	0.7^{a}
Sawdust	7.81^{a}	12.67^{a}	4.38^{d}	7.55^{d}	2.12^{b}	0.14^{c}	0.14^{c}	0.09^{b}	0.93^{c}	0.44^{c}	5^{b}	2^{a}	7^{b}	0.3^{b}

Note: Means of feedstocks on rate with same letter within column are not significantly different by DMRT $P < 0.05$.

Table 4: Abundance of nutrients availability in the plant materials, its biochar and compost

Plant Materials	Plant material	Biochar	Compost
	Nutrients Available	Nutrients Available	Nutrients available
Cassava peels	Ash content, Moisture content, OC, OM, C:N, Ca:Mg, K:Mg	K, P	Ca:K
Gliricidia cuttings	P, K, Ca, Mg	Moisture content, OC, OM, C:N, K:Mg	TN, OC, OM, Ca:Mg, Ca:K
Neem clippings	NIL	NIL	Mg, Moisture content
Panicum cuttings	NIL	K, Ash content	Ash content, Ca:Mg, K:Mg
Maize stover	NIL	TN, Mg	K, Ca, Ca:Mg
Sawdust	NIL	Ca, Ca:Mg, Ca:K	NIL

NIL – Nutrient status were low/ negligible/ non-available.