TRANSFORMATION OF BIORESOURCES WASTE INTO USEFUL SOIL RICHED-NUTRIENTS FOR CROPS YIELD ENHANCEMENT

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Abstract

Development in technology and innovation has encouraged the exploration of bioresources waste in different research field for wealth creation. These bioresources waste constitutes environmental nuisance, however has important potentials which when converted into soil amendment tends to improve nutrients mobility without affecting the natural environmental conditions when compared to the negative impacts of chemical fertilizer. The aim of this work therefore is to transform ocw dung and jatropha cake waste into organic amendment for crop yield enhancement. The aim was achieved by producing the amendment from cow dung and jatropha cake as carrier through composting processes where 5 kg of the mixed waste was charged into a biodigester. Temperature, pH and moisture content were monitored throughout the process, and subsequently been converted into organic amendment after subjecting the matured compost through fermentation process. The produced soil amendment was subjected to biochemical analysis whose efficiency on the soil properties and plant germination index were investigated afterwards. The moisture content of the compost stabilizes at 50 % in which the temperature dropped from 50°C to 25°C at the maturity stage. The active microorganism identified in the produced amendment consist of bacteria and fungi with cell counts of 4.3 × 107 and 1.7 × 107 cell/g respectively, which enhanced the soil properties by improving its water holding capacity by 91 % and organic carbon by 84.5 %. The improved in the soil properties efficiently contributed to the average root length and shoot length of 1.46 and 5.66 cm respectively for organic amendment plant when compared to the control sample whose average values of root and shoot lengths were 0.3 and 0.6 cm respectively. It is therefore, concluded based on the investigation carried out that, bioresources wastes were successfully converted into useful organic amendment to improve soil properties.

Keywords: Organic amendment, water holding capacity, plant germination index

Introduction

There is a growing alarm on soil degradation, as universal need for food, water, energy, and raw materials persists at unparallel amount (Liu et al., 2019). The shortage of feat to meet up with these needs can be without difficulty result in unpleasant wave influence in human race. According to Corato, (2020), the universal land outlook approximates that one third of the universal land surface is harshly degraded, which has harmful effect on the comfort of no less than 3.2 billion populace traversing all continents. This leads to death of biodiversity and ecology services resulting to a financial loss of roughly 10 % of the globe's yearly overall produce in 2020 (Mendonca et al., 2021). In Africa, soil degradation produces a yearly damage of 3.51 megagrams of soil for each hectare annually (3.51Mg/ha) from erosion susceptible lands (Ballardo et al., 2021). These effects harmfully influence soil quality as the water holding capacity is abridged due to the soil structural instability and the leaching of nutrients (Adebayo et al., 2021; Malta and Anna, 2021). To provide for a rising populace whilst adjusting to climate change, shielding and reinstating soils are necessary to sustain bot just the soil natural properties but also the environment (Malta and Anna, 2021; Heshan and Latif, 2021).

There are a number of ways to conquer the extended catalogue of challenges from land degradation to soil losses and loss of biodiversity. One of the reinstating methodologies to improve and lessen soil degradation is by maintaining and boosting soil organic matter levels as reported by Abdulkadir et al., (2021) and Xianfang et al., (2021)). The boosting of soil organic matter improves the aggregation of soil particles, consequently enriching aggregate stability and soil structure (Abdulkadir et al., 2021), because firm soil aggregates reduce the danger of soil plane closure and related plane overflow configuration and thereby encourages water infiltration and also the soil water retention capacity (Pane and Anubha, 2021).

More so, the integration or recycling of bioresources materials such as organic manure, crop remains and other organic waste materials are generally used to raise and preserve soil organic matter but the direct application of these raw materials without adequate treatment are unsafe and not scientific (Gai et al., 2019; Kranz et al., 2020). However, composting by biological degradation and treatment by organic waste are one of the approaches used to achieve soil amendments (Kranz et al., 2020;

Ghulam et al., 2021). These amendments are capable of upgrading soil carbon standard and related ecological unit services when applied to soil as reported in the work of Choudhary et al., (2018). Furthermore, proper treatment of these waste for soil amendment can also be justify owing to the opulence in constituents of the treated compost with organic supplies, various nutrients (e.g., N, P, and K), microbiomes, and water that are critical for on-land cultivation. This makes composting an appealing alternative for the aim of soil reclamation (Asses et al., 2019; Ghulam et al., 2021).

More so, considering an average 98 million tons of agricultural waste and 28 million tons of animal waste been generated annually in Nigeria as reported by Anar et al., (2019) and Jangir et al., (2019) without adequately harnessing them through the waste management system, thereby adding to the existing environmental pollution problem and also depriving country the economic value of these waste into wealth potential. The need to utilize the abundance availability of these raw materials to justify this study. Therefore, this work was aimed to produce organic amendment and study its impact on soil properties and germination index of plant.

Materials and Methods

Preliminary analysis of the compost.

The chemicals-HCl, NHO_3, H_2SO_4, H_2O_2 used were purchased from Cardinal chemical store, Zaria while the glass wares (beaker and measuring cylinder) used were obtained from Hadis store, Zaria. The cow dung, soil samples and Samaize-17 specie used were obtained from Institute of Agricultural Research (IAR), Ahmadu Bello University, (ABU) Zaria. The jatropha cake waste used as carrier was obtained from National Research Institute for

Chemical Technology.

The total organic carbon (TOC), total nitrogen (TN), carbon to nitrogen ratio (C/N), available potassium (K_2O) and phosphorous (P_2O_5) of the compost pile were analyzed before and after composting process. The total organic matter (TOM) was estimated by adopting the method used in the work of Aftab et al., (2019). Ammonium (NH_{4+} N-) and nitrate (NO_3-N-) were done using Keeney and Nelson, techniques, which was adopted from the work of Gai et al., (2019). The pH and electrical conductivity (EC) were done by determining the parameters electronically in aqueous solution (1:6 w/v) of samples as reported by Adebayo et al., (2019).

Production of the soil amendment

5 kg of compost pile, consisting of dried cow dung and jatropha (carrier) cake were charged into bioreactor in ratio of 70 % to 30 % for composting processes. The composting process was monitored in terms of temperature, pH and moisture content of the system for two weeks, after which fermentation process was done by dissolving mixture of 0.5 kg of brown sugar and 2 liters of water into the reactor. The solution was mixed and sealed tightly for 5 days, to form active substrate for the microorganism to strive. Sample was taken from the liquid product formed from fermentation process for analysis to ascertain the active microorganisms present. This was allowed to stand and monitored for further three weeks before the organic amendment produced was discharged and sample was taken for biochemical analysis and nutrient content of the fertilizer by adopting standard method using nutrient agar (NA) as media for the enumeration of bacteria while potato dextrose agar (PDA) was used for fungi, and using micro-Kjeldahl digestion methods for the nutrient contents.

Determination of the soil type

The particle size distribution was determined following the Bouyoucos hydrometer method as described by Ozlu and Kumar, (2018); of which 50 ml of 6 % H2O2 was added to 500 g of sieved soil sample in a beaker. The beaker was covered with watch glass and then placed in a hot-water bath until organic matter is oxidized before been removed to cool. The suspension was made to the mark with distilled water, in a 1000 ml cylinder with the rubber stopper put tightly. The solution was stirred vigorously with a plunger and the stirring time was recorded. A hydrometer was lowered into the suspension for 40s and the hydrometer reading was taken; the suspension temperature was taken as well. The suspension was stirred again and was left undisturbed for the second hydrometer reading to be taken after 2 hrs. The values are 480 gkg-1 320 gkg-1 and 200 gkg-1, which is equivalent to 89.8 wt.%, 7.9 wt.% and 2.3 wt.% compositions respectively. The percentage of sand, silt and clay were computed using the following relationships;

$$\text{Clay}(\%) = Wc/W \times 100 \quad (1)$$

$$WC = R2HR - RB \quad (2)$$

$$\text{Silt}(\%) = Wsi/W \times 100 \quad (3)$$

$$Wsi = R40s - RB) - (R2HR - RB) \quad (4)$$

$$\text{Sand}(\%) = 100 - (\%\text{silt} + \%\text{clay}) \quad (5)$$

Where: W = weight of sieved soil sample, WC = weight of clay), R2hr = 2 hrs hydrometer reading, RB = blank hydrometer reading, R40S = corrected forty seconds reading, Wsi = weight of silt.

The textural class of the soil was determined using textural triangle software. The values obtained for percentage clay, sand and silt was inserted into the sections provided in the software to give the result of the soil textural class. Plate I shows soil texture classification triangle used for the clarification guide.

Soil analysis before and after amendment

An undisturbed (core sample) and disturbed soil samples were collected at random from different points at 30 cm depth. The soil samples were collected from the Institute

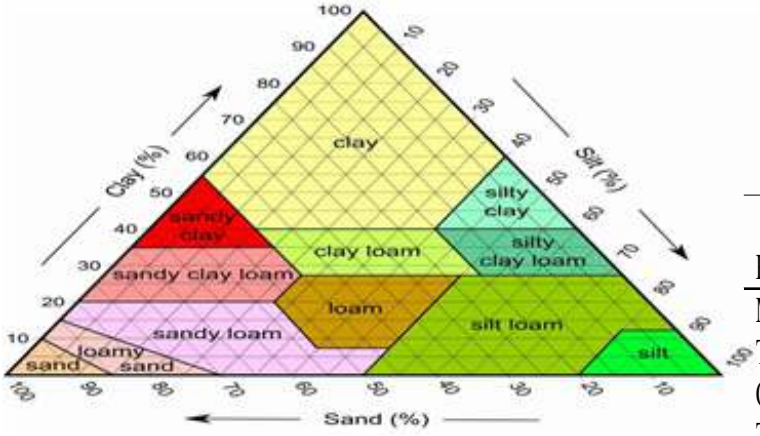

Plate I: USSD soil texture classifications (Ruben et al., 2015)

for Agricultural Research Farm, Ahmadu Bello University Zaria. This area was abandoned due to its low fertility as a result of degradation by intense agricultural cultivation. The disturbed sample was spread on a platform and thoroughly mixed together to form a composite and thereafter it was air-dried and sieved using 2-mm sieve. Percent gravel to total soil was calculated. However, the undisturbed sample was taken without any alteration in the 15 cm core for soil water holding capacity analysis.

Studying the efficiency of the organic amendment on the soil

A phytotoxicity analysis on the basis of germination bioassay was made by means of the technique described by Dukuziyaturemye et al., (2020), where 10 g of the produced organic amendment was weighed in ten different sample bottles, mixed with 100 ml of distilled water and then enthused for 24 hrs. in each case. The mixtures were then stirred for 20 min and the solution filtered through Whatman No. 42 filter paper. The filtrates were diluted. Samaize-37seeds were the specie of maize used in which two seeds were slumped in 9-cm-diameter petri dishes lined with a filter paper. 5 ml of extract was pipette into each petri dish and petri dish with 5 ml distilled water was used as a control. The petri dish was 10 in numbers in each treatment (organic fertilizer treatment and control). Each petri dish was freely covered to diminish water loss and allow air penetration. The petri dishes were kept warm for seeds to germinate. Every experiment was replicated. Germination of seeds and length of root and shoot size dimensions were carried out after 72 h of the investigation, where the average values were recorded. The germination index (GI) was obtained by multiplying germination (G) and relative root growth (RRG), together expressed as percentage (%) of the control values as illustrated in Equation (6). The germination vigor was as well calculated by the means of Equation (7).

Germination index (GI) =

Table 1 shows the properties of the compost piles before and after the composting process. As shown in the table,

Table 1: The main characteristics of initial and final co-composting

Parameters	Before co-composting	After co-composting
Moisture content (%)	43.40	58.71
Total carbon (%)	27.65	22.98
Organic matter (%)	47.67	39.62
Total nitrogen (%)	2.42	3.43
P_2O_5 (%)	4.68	6.16
K_2O (%)	1.36	1.97
C:N	11.45	9.56
pH	5.7	7.8
Color	Brown	Black
Electrical conductivity (ds/m)	0.70	0.30
NH_4 (%)	0.0028	0.60165
NO_3 (%)	0.0896	0.0168

the initial moisture content of the compost pile was 43.40 %, it was increased to 58.71 % at the completion of the processes, which are still within the range (40-60) % of standard specifications for rapid composting as reported by Corato, (2020). Chemical reaction occurs at this optimum moisture content in which microorganism movement and transportation of nutrient from one point to another within the system are enhanced. The availability of sufficient nitrogen which was improved subsequently from 2.42 % to 3.43 % through the microorganism activities withing the composting system was responsible for synthesis of cellular material, amino acids, and proteins within the system while the amount of carbon present was used as a source of energy and for growth of microbes. As observed from the results presented in Table 1, the availability of carbon was reduced from 27.65 % to 22.98 % due to its consumption during the composting process. Also, the organic matter load within the system was reduced from 47.67 % to 39.62 % by the activities of microorganism as shown in the table, which further justified the C: N values deprecation from 11.4 % to 9.56 %. These agree with trends reported in the work of Marta and Anna, (2021), which is also a function of the improvement observed on the increased values that were recorded as 4.68 %-6.16 % and 1.36 % -1.97 % for P_2O_5 and K_2O contents respectively.

The variation in pH values of the composting system over 30 days investigating period was presented in Figure 1. As shown in the figure, during the mesophilic period (the first two days), the pH value was 7.91 after which it raised to 9.85 during the thermophilic stage. The rise in the pH value is due to the liberation of ammonia gas as a result of rapid

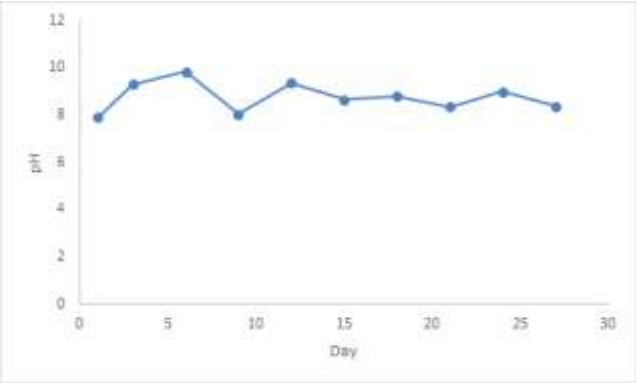

Figure 1: pH profile of the co-composing process

breakdown of waste by microbes as reported by Marta and Anna (2021). However, the pH value at day 14th was observed to have reduced to 8.08 but still in alkaline medium. This may be as a result of the organic acids released and elevated amount of CO2 absorbed into the system from the extreme breakdown of carbohydrates. This trend is in good agreement with the work of Adebayo et al., (2018) and Ballardo et al., (2021) which reported that, the value of pH in composting processes rises with time due to the activity of microorganisms which resulted in the liberation of ammonia gas during the breakdown of organic matter.

Moisture content profile of the co-composting process

Moisture content of composting is one of an important factors required as microorganisms needs water to strive and transporting of dissolved nutrients needed for metabolic and physiological activities, because low moisture content led to decrease in respiration while high moisture content increases it. Figure 2 depicted the moisture content profile for the co-composting process

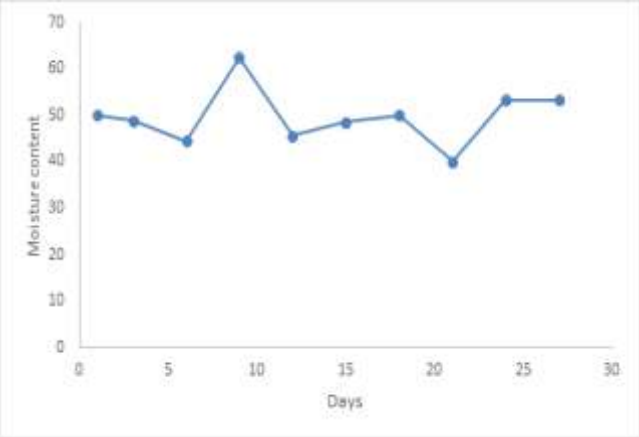

***Figure 2**: Moisture content profile of the co-composting process*

As shown in Figure 2, the initial moisture content of the compost system was 50 %, which is considered minimum as reported in the work of Liu et al., (2019). As observed from the figure on the 3rd and 5th day of composting, the moisture content reduced to 45 % and 44 % respectively. These trends in moisture content of the system are similar to what were reported in the work of Pane and Anubha, (2020). The decrease in moisture content as observed from Figure 2 may be as a result of the high heat energy generation due to microbial activities within the composting system, leading to high water loss. However, the moisture content increased to 63 % on day 9 of the investigation due to excess water accumulated within the system but subsequently reduced to 43 %, then rise to 45 % on days 11 and 13 respectively. The moisture content continued to reduce and increase during the observation as shown in Figure 2 until it stabilizes on 50 % from days 25th to 29th. These variations observed was due to the activities of microbe to completely break down of the organic matter until maturity stage was achieved.

Temperature profile of the co-composting process

Figure 3 shows the variations in the temperature of the composting system withing the composting investigation period

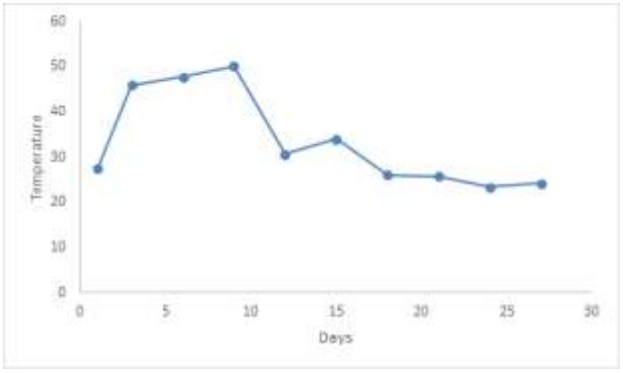

***Figure 3**: Temperature profile of the co-composting process*

As shown in Figure 3, the initial temperature at the beginning of investigation was 28°C but increased rapidly to 45.95°C and 47.80°C on the 3rd and 7th day respectively. Th3 rise in temperature may be as a result of activities of breakdown of organic matter by the microbes, thereby releasing heat. This is in agreement with related report in the work of Ghulam et al., (2021). The temperature of the composting system rose to 50.20°C on the 9th day as a result of intense decomposition of the available organic matter, which is sufficient enough to eliminate any pathogen present in the system. The system temperatures were observed to have gradually decreased from day 13th to 29°C but slightly increased to 33°C on the 15th day before it decreased to 27°C on day 17th and finally stabilized at 25°C from the 23rd day until the process was completed.

Microbial analysis of the produced organic amendment

The microbial analysis of organic fertilizer is shown in Table 2. As shown in the table, the active microorganisms in the produced organic amendment are Bacillus SP (bacterial) with cell count of 4.3 X 107 cell/g which helps in maintaining mesophilic temperature. Also, the active fungi present are Aspergillus Fumigatus, Aspergillus Versicolor and Penicillium SP with the same cell count of 1.7 X 107 cell/g. These fungi present are the microorganism that continuously recycling carbon and nitrogen

Table 2: Microbial analysis results of the produced organic amendment

Active microorganism	Microorganism type	Cell count (cell/g)	Function	Moisture content (%)
Bacillus SP	Bacteria	4.3×10^7	P-solubilizer	40
Penicillium SP	Fungi	1.7×10^7		
Aspergillus versicolor	Fungi	1.7×10^7		
Aspergillus fumigatus	Fungi	1.7×10^7		

Table 3: The main characteristics of the experimental soil

Soil characteristics	Value (Before application)	Value (After application)
Sand (gkg^{-1})	480	
Silt (gkg^{-1})	320	
Clay (gkg^{-1})	200	
Soil texture	Sandy loam	
pH	6.5	7.3
EC (ds/m)	0.13	1.05
TOC (%)	0.02	0.13
TN (%)	0.0028	0.0046
P_2O_5 (mg/kg)	0.0033	0.0056
Ca++ [cmol (+) kg^{-1}]	2.60	3.21
Carbon (gkg^{-1})	1.5	9.7
Water holding capacity (%)	0.49	5.3
ECEC [cmol (+) kg^{-1}]	4.21	4.98

As shown in Table 3, the organic carbon in the soil was 1.5 gkg-1 which is very low compared with the standard specification of >15 as reported by Xianfang et al., (2021). The low organic carbon content observed may be attributed to the exhaustion of the organic matter in the soil as a result of soil degradation by continuous cropping without replenishing the used nutrients which were loss during soil leaching. The improvement of the organic carbon through the effect of organic fertilizer incorporated does not meet the required specification, however, the effect was shown as it was increased by 91 % which proved that, the soil amendment with was good. Also, the low water holding capacity of the soil before the application of the amendment was recorded to be 0.49 % as shown in Table 3 which further justified the reason for low organic matter content observed in the soil. It was improved to 5.3 % with the incorporation of the organic amendment in the soil which improved the water holding capacity of the soil.

As it was further observed from Table 3, the initial effective cation exchange capacity (ECEC) of the soil was 4.21cmol+ kg-1, which was improved afterwards by the effect of organic fertilizer incorporated. The pH of the soil recorded as 6.5 was improved to 7.3 with the impact of organic fertilizer on the soil, which is suitable for crop growth.

Effects of the soil amendment on germination index of plant

Table 4 show the impact of organic amendment on plant roots and shoot lengths growth and that of control sample. As presented in the table, the root length for plant 1 in the organic amendment incorporated plant was 0.9 cm which is 33.3 % higher than the one in a control sample when compared based on the same experimental treatment condition. Also 1.9 cm root length was observed for plant 2 in organic amendment plant while 0.5 cm was recorded in the control sample as shown in Table 4. More so, the trends in shoot length of all the plants in organic amendment incorporated sample are better in terms of productivity and yield when compared to of control samples. The evidence was observed on the average shoot length of 5.66 cm as compared to 0.6 cm in a control sample. Therefore, the effect of organic amendment on the soil and plant roots can be justify with efficiency of the improved soil properties as observed in this investigation.

Table 3 : *Average root and shoot lengths in organic amendment and control plants experiment*

	Organic amendment incorporated plants		Control plants	
Plant	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)
1	0.9	2.6	0.6	1.0
2	1.9	7.7	0.5	1.1
3	1.5	8.6	0.5	1.0
4	1.9	2.9	0.3	0.7
5	1.1	6.0	0.0	0.2
6	1.8	7.5	0.2	0.5
7	2.3	9.5	0.0	0.1
8	0.7	3.0	0.4	1.5
9	1.1	4.1	0.1	0.5
10	1.4	4.7	0.4	0.5
Average	1.46	5.66	0.3	0.6

Plate I (a and b) show some of the plant roots investigated during the experimental process



Plate I: Plant roots of the (a). organic amendment sample and (b). Control sample

Conclusions

It can be concluded at the end of this investigation that, the produced organic amendment characterized with 40 % moisture content contained bacillus SP, penicillium SP, aspergillus versicular and aspergillus fumigatus as its active microorganism. More so, the produced organic amendment improved the water holding capacity of the soil by 91 % and the soil organic carbon by 84.5 % which are functions of the average root and shoot lengths of 1.46 cm and 5.66 cm respectively recorded for organic fertilizer amended soil compared to the 0.3 cm and 0.6 cm average lengths obtained for the control sample. Therefore, the produced amendment impacted the soil efficiently.

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