Formulation of Natural Fortifiers from Readily Available Materials for Nutrient Enrichment of Organic Fertilizers

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ABSTRACT

Studies have shown that organic fertilizer, a product of biodegradable organic matter, is not popular among Nigerian farmers because of its low quality. To alleviate this problem, this study was designed to explore the effect of nutrient-rich materials on quality of fertilizer made from market organic wastes. It adopted an experimental study design, comprising organic fertilizer preparation, fortification with natural fortifiers, farm plot experiments and laboratory analyses. The experiment was laid out in a randomized complete block design with factorial arrangement and three replications. The main plots comprised three crops - maize (cereal), soybean (legume) and yam (tuber) while five different fortified organic fertilizers at three rates of applications -2.0, 2.5, and 3.0 ton/ha and control (organic fertilizers without fortification) - formed subplots. Nutrient-rich materials sourced from animal, plant and rock changed the chemical composition of organic fertilizer made from market wastes and yielded better agronomic performances than the synthetic fertilizer. Hence, fortification of organic fertilizer with natural materials which are readily available and environmentally friendly should be promoted among the farmers.

1. INTRODUCTION

In Nigeria and many other developing countries, synthetic fertilizers account for the largest source of nutrients such as nitrogen, phosphorus and potassium that are needed for plant growth (Lenis and Liverpool-Tasie, 2017). However, the use of compost or other organic-based fertilizers has been employed only to a limited extent. Despite this, synthetic fertilizer application, estimated at 13 kg/ha in 2009 by the Federal Ministry of Agriculture and Rural Development, is far lower than the 200 kg/ha recommended by the United Nations Food and Agriculture Organization (FAO) (Otu et al., 2014) for soil in Nigeria. The low fertilizer application is acknowledged to be among the many reasons for low agricultural productivity in Nigeria (Lenis and Liverpool-Tasie, 2017). According to Takeshima et al. (2015) during 2000/01-2002/03, the average fertilizer use in Sub-Saharan Africa (excluding South Africa), estimated at 9 kg/ha, was much lower than it is obtainable elsewhere in the world (for example, 86 kg/ha in Latin America, 104 kg/ha in South Asia, and 142 kg/ha in Southeast Asia). In the late 1970s, inorganic fertilizers such as urea, Single Super-phosphate (TSP) and different formulations of NPK (nitrogen, phosphorus and potassium) were heavily subsidized up to 95% (Takeshima et al., 2015). But after subsidy was removed in the 1990s, the price of fertilizer skyrocketed and corrupt practices prevented timely and efficient distribution of it to farmers (Obi-egbedi and Bankole, 2017).

Chemical fertilizers are made in factories by turning nitrogen gas into ammonia and by treating rock phosphate with acid while organic fertilizers are derived naturally from plants and animals and also include minerals that occur naturally (Vinneras, 2002). One major advantage of chemical fertilizers is that they quickly break down to provide specific nutritional needs to plants. However, they normally cause rapid release of nutrients and possible unbalanced growth (Rowlings et al., 2013; Fernando et al., 2015) and salty environment which wreak havoc on plants and soil through over-fertilization and water pollution (Vance et al., 2003; Carey et al., 2012). Organic fertilizers contain relatively low concentrations of actual nutrients and depend on soil

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organisms to break them down to release these nutrients. Since nutrient released by microbial activities, in general, occurs gradually over time, one potential drawback is that the organic fertilizers may not release enough of their principal nutrients when the plant needs them for growth.

According to Marion (2000), organic fertilizers perform important functions which the chemical formulations do not. Organic fertilizers tend to bring the balance back to the soil and provide long-term fertility. They also impact significant physical and biological properties by increasing water-holding capacity of the soil; enhancing soil stability, structure and texture (Ludwig et al., 2011); improving soil microbial activities; controlling weed and common pest growth; minimizing the dependence on expensive inorganic fertilizers; preventing soil erosion; binding toxic chemicals in soils and making them unavailable to plants; and reducing soil and water pollution. Various studies have shown the importance of organic nutrient sources in improving maize yields (Heluf, 2002; Mucheru-Muna et al., 2007). The decline in yam yields associated with loss of soil fertility has led to the conclusion that yam requires high level of nutrient for growth (O'Sullivan and Ernest, 2008). Nitrogen (N) and potassium (K) are largely stored in the tubers (Diby, 2005; O'Sullivan and Ernest, 2008) while the calcium (Ca) is mainly accumulated in the leaves and returns to the soil with dead leaves (Diby, 2005). Soybean has been described in various ways. Some call it the "miracle bean" or the "golden bean" because it is a cheap, protein-rich grain. It contains 40% high quality protein, 20% edible vegetable oil, and a good balance of amino acids (Pawar et al., 2011).

Increasing the nutrient levels in the organic fertilizers and optimizing its quality is a great challenge. There have been, and there will continue to be, efforts towards developing and refining methods of improving and up-grading the quality of stable and mature compost, also known as organic fertilizer, with cheap, locally and readily available organic materials up to the level that could be compared to the synthetic fertilizer counterparts. Sridhar et al. (2001) and Adeoye et al. (2008) noted that supplementing with natural sources of fortifiers is more environmentally friendly than opting for chemical sources. Up till now, no one universally accepted and applied method for upgrading organic fertilizer quality into chemical fertilizer status exists. Hence, any research in this direction may likely provide solution to the problems inherent in the organic fertilizers and promote their usage among the farmers. Therefore, the objectives were to characterize various natural and synthetic fortifiers for their nutrients and selected heavy metals; produce organic fertilizer, fortified the fertilizer for crop specific use; and determine the effects of fortified organic fertilizers on agronomic parameters of test crops.

2. METHODOLOGY

2.1 Description of the study area

The experiment was conducted in Ibadan, Nigeria. Ibadan (Yoruba: Ìbàdàn or fully Ìlú Ẹ̀bá-Ọ̀dàn, the town at the point of the savannah and the forest) is the capital city of Oyo State and the third largest metropolitan area in Nigeria in terms of population after Lagos and Kano, as the 2006 Nigerian Census revealed. It is located in south-western Nigeria, 128 km inland Northeast of Lagos and 530 km Southwest of Abuja, the Federal Capital Territory. It is also a prominent transit point between the coastal region and the areas to the North. In addition, about 36.25 km^2 (34.9% of the land area) is allotted for land use (such as residential area, public buildings and facilities, markets, industrial and commercial areas as well as educational institutions, amenities and open spaces. The remaining 63.75 km^2 is allotted for non-urban uses such as fallow land, forest reserves, farmland and water environment (Areola, 1992). The field was located behind Alesinloye Waste Recycling facility, Alesinloye Market, Ibadan. At the facility, all organic wastes generated in the market were converted to organic fertilizer while plastic and nylon wastes were recycled into useful materials such as plastic pellets and chips for plastic manufacturing industries. The recycling complex is situated next to the market abattoir where an average of 30 cows is slaughtered daily. Animal waste from the abattoir including blood and bone was also used in the production of organic fertilizer in the facility.

2.2 Materials

The test materials used for fortifying organic fertilizer comprised both natural and synthetic materials. Natural materials were Plant-based (PB), Animal/Human-based (AB) and Rock- based (RB). Synthetic materials were urea and Single Super-phosphate (SSP). The urea contained 45% N per 50 kg bag and had 18% P_2O_5. Plant-based included

Cotton Seed Meal (CSM), Palm Kernel Shell (PKS), Neem Seed (NS) and Palm Kernel Residue (PKR) all which were sourced from Ibadan neighborhoods. Animal-based comprised of Chicken Feathers (CF), Hoof Meal (HM), Horn Meal (HM), Human Hair, and Bone Meal (BM). Human hair was collected from the market at barber's shops; chicken feather was collected from fowl sellers' shops behind the recycling premises; and, the rest were sourced from Alesinloye Market abattoir beside the complex. Rock-based comprised Rock Phosphate (RP) was sourced from Agronomy Department, University of Ibadan. In addition, test crops were maize (*Zea mays* L), Soybean (*Glycine max*; TX 114) and Yam (*Dioscorea rotundata* Poir), representing cereals, legume and tuber respectively. The maize had commercial name of 'Oba Super 2', yield capacity of 5 to 7 ton/ha and germination rate of 90%. Both maize and soybean were sourced from the Generic Laboratory of International Institute for Tropical Agriculture (IITA), Ibadan; while the yam was sourced from a local market in Ibadan. Also, soil samples were taken from the farm plots before crop planting at depth of 0-10 cm for baseline data.

2.3 Study design

The study design was experimental and comprised compost preparation and fortification, farm plot experiments and laboratory analyses. Plot experiments design was simple Randomized Complete Block Design (RCBD) with three replications. Main plots were for three crops selected for the study - maize (cereal), soybean (Legume) and yam (tuber) - while five different Fortified Organic Fertilizers (FOFs) at three levels of applications -2.0, 2.5, and 3.0 ton/ha, and control plot, applied with ordinary compost without fortification, formed subplots. This translated to 0.20, 0.25 and 0.50 kg/plant, respectively (i.e., one 50 g bag was used for 250, 200, and 100 plant stands, respectively). In the maize and soybean subplots, each of the treatments and control plot was designed in 3×3 factorial with three replications. For yam, 2×3 factorial was used. All the plots were labelled according to the type of fertilizer formulation applied to them viz: Control which is ordinary organic fertilizer (compost) without fortifiers (C), PB, AB, RB, Organic-based fertilizer (OM, mixture of PB, AB, and RB), and mixture of urea and SSP (SC, synthetic chemical).

2.4 Methods of data collection

The data were collected using different methods; laboratory measurements were used to appraise the quality of raw organic wastes, organic fertilizers, natural fortifiers (nutrient-rich materials), chemical fortifiers, soil samples and quality of FOFs produced, using standard analytical methods as described by Motsara and Roy (2008). The following chemical parameters were determined: total organic-carbon (OC), total nitrogen (TN), C:N ratio, total phosphorus (P), calcium (Ca), magnesium (Mg) and sodium (Na) as well as some selected heavy metals such as lead (Pb), chromium (Cr), nickel (Ni), zinc (Zn), manganese (Mn), Iron (Fe) and Cadmium (Cd). Samples taken from the materials were air-dried, milled and digested for the purpose of phosphorus and heavy metal determination, using spectrophotometry. About 0.2 g of each sample was digested with nitric, perchloric and sulphuric acid mixture in the ratio of 5:1:1 in a 100 mL conical flask (Motsara and Roy, 2008). Determination of total phosphorus in the samples was carried out spectrophotometrically, using the Mo (molybdo-vanadate) blue colour method of Murphy and Riley (1962). Total carbon content of the samples was determined according to Walkey Black wet oxidation method (Walkley and Black, 1934) and total nitrogen was determined, using regular Macro-Kjeldahl method (Kjeldahl, 1883). Potassium content of raw samples was determined according to Mehlich 3 procedure (Mehlich, 1984).

Prior to laboratory analyses, pH of samples was measured with the aid of a pH digital meter. Also, moisture content and dry matter content were determined using AOAC Official Method (2005) by measuring 2 g of the sample into a previously weighed crucible. The crucible plus sample was transferred into the oven set at 100 °C to dry to a constant weight for 24 h. At the end of the 24 h, the crucible plus sample was removed from the oven and transferred to the desiccator, cooled for ten minutes and weighed. The values obtained were subjected to Equations 1-2:

$$\%\ \text{Dry Matter (DM)} = \frac{W_3 - W_0 \times 100}{W_1 - W_0} \quad (1)$$

$$\%\ \text{Moisture} = \frac{W_1 - W_3 \times 100}{W_1 - W_0} \quad (2)$$

Where: W_0=weight of empty crucible, W_1=weight of crucible plus sample, W_3=weight of crucible plus oven-dried sample, and %Moisture=100 - %DM.

Organic fertilizer was produced by mixing sorted organic waste with cow intestinal waste in ratio 3:1, following the method used in the facility (Hammed et al., 2011). Farm practices and performances of different FOFs on agronomic parameters (growth and yield data) of the three test crops on the field were also monitored. Agronomic data measured included number of leaves, by counting; plant height, leave area, and stem girth (in centimeters) by metric rule; and crop yield by weighing scale. Maize leaf area was calculated thus: L × B × 0.745 (Agboola and Unamma, 1991). Plant height was measured as the distance from the base of the plant to the height of the first tassel branch and ear height as the distance to the node bearing the upper ear (Badu-Apraku et al., 2010).

2.4.1 Procedures for fortification of organic fertilizer with natural fortifiers

Results obtained from baseline chemical analyses of all the materials were used to determine the amount of fortifiers needed to enrich the organic fertilizer. The fortification was carried out in view of two major macro-nutrients in fertilizer (N and P). Initial levels of these nutrients in the organic fertilizer were increased to P=2.5% and N=3.5%, in accordance with the national quality standard of organic fertilizer (Otu et al., 2014). The dilution formula (Equation 3) was used to fortify the compost and achieved all the formulations tested on the field.

$$C_1W_1 = C_2W_2 \tag{3}$$

Where, C_1 is an initial level of N or P in the organic fertilizer, C_2 is the final level of N of P in the formulation, W_1 is the quantity of the fortifier that is required to produce the quantity that is needed (W_2). For instance, nitrogen and phosphorus fortification using RB fortifier was carried out viz.

Nitrogen: where C_1=9.4% N, W_2=1.5 kg, C_2=2.5% N, W_1=?

$9.4 \times W_1 = 2.5 \times 1.5$

$W_1 = \dfrac{2.5 \times 1.5}{9.4}$ = 0.399 kg (i.e., 399 g) of hair

Phosphorus: where C_1=17% P, W_2=1.5 kg, C_2=1.5% P, W_1=?

$17 \times W_1 = 1.5 \times 1.5$

$W_1 = \dfrac{1.5 \text{ x } 1.5}{17}$ = 0.132 kg (i.e., 132 g) of phosphate rock

RB formulation = 399 g Hair + 132 g Phosphate Rock + 969 g Organic fertilizer

2.4.2 Procedures for plot experiment

Size of beds constructed for each type of crop - maize, soybean or yam - was 1 m × 1 m = 1 m^2. For the maize and soybean, 9 seeds were planted per bed. In the case of yam, only four yam tubers could be planted due to the size of a tuber. Distance of 45 cm was maintained between one crop stand and another. Quantity of fertilizer was estimated on assumption that 1 ha of land is equivalent to 10,000 m^2. As such, 2.0 ton/ha was translated to 0.2 kg of fertilizer per 1 m^2 (size of a bed). For maize and soybean with 9 seeds per bed, each plant was applied with 22 g (i.e., 0.2 kg ÷ 9 = 0.022 kg or 22 g). In the case of a yam bed with 4 seeds, each plant was applied with 50 g of fertilizer (i.e., 0.2 kg ÷ 4 = 0.05 kg or 50 g). Similar calculation was used for other two rates of applications, 2.5 ton/ha and 3.0 ton/ha, carried out in this study. A total of 72 yam tubers (each yam weighed 0.55 g) were planted on the yam ridges. Thrash removed from the ground during the clearing was used as mulch and FOFs were applied to the yam using ring method, a month after planting and at the first appearance of shoot. Fertilizer application to maize and soybean was also carried out, using ring method - 3 cm deep and 5 cm away from stem two weeks after germination. Effects of FOFs on agronomic parameters (number of leaves (NL), plant height (PH), stem girth (SG), leaf area (LA) and crop yield) were assessed in these experiments.

3. RESULTS

3.1 Chemical composition of samples

The baseline characteristics of soil, nutrient and heavy metal compositions of fortifiers and organic fertilizer before fortification are indicated in Table 1, Figures 1 and 2. The soil had more sand content (79.2±0.0%) than both silt (13.4±0.0%) and clay (7.4±0.0%). Levels of macro nutrients were: N (0.2±0.0%); P (2.6±0.0%) and C (0.9±0.0%) (Table 1). Urea, organic mixture and bone were very rich in phosphorus and, in addition to this, urea had the highest quantity of nitrogen followed by cotton, animal blood and neem (Figure 2). Among all the materials, blood, followed by the bone, was found with the least quantity of heavy metals with the exception of iron. Organic fertilizer contained the highest level of Zn while neem and horn had the highest quantity of Cu (Figure 2).

Table 1. Characteristics of soil used for plot experiment

S/N	Parameter	Value (Mean±SD, n=4)
1	IM KCL	6.9±0.0
2	pH (H_2O)	7.6±0.0
3	E.C_{25} (mmho/cm)	18.0±0.0
4	Org. C (%)	0.9±0.0
5	Total N (%)	0.2±0.0
6	Av. P (mg/kg)	2.6±0.0
7	Sand (%)	79.2±0.0
8	Silt (%)	13.4±0.0
9	Clay (%)	7.4±0.0
Exchangeable bases (Cmol/kg)		
10	Ca	0.5±0.0
11	Mg	1.0±0.0
12	Na	2.0±0.0
13	K	0.7±0.0
14	Ex. Acidity	0.2±0.0
15	CEC	4.50±0.0
Extractable micronutrient (mg/kg)		
16	B. Sat	95.6±0.0
17	Mn	268.1±0.1
18	Fe	186.0±0.1
19	Cu	2.8±0.0
20	Zn	7.5±0.0

Organic carbon was found highest in C while nitrogen and carbon were higher in all the FOFs compared to P and K. Effects of fortification were more predominant in TN and OC than in other nutrients as shown in Figure 3. There were no significant differences in the nutrient values of all formulations. Chemical analysis of FOFs revealed organic-carbon (%): 33.2±0.0, 38.4±0.2, 27.7±0.1, 34.8±0.0, 28.4±0.2, 32.8±0.21; TN (%): 5.69±0.0, 5.74±0.0, 5.85±0.0, 6.05±0.0, 6.15±0.0, 3.21±0.0, phosphorus (%): 0.3±0.0, 0.5±0.0, 0.2±0.0, 0.8±0.0, 0.2±0.0, 0.7±0.1 and potassium (%): 0.5±0.0, 0.7±0.0, 0.4±0.0, 1.0±0.0, 0.4±0.0, 0.9±0.0 for PB, AB, RB, OM, SC and C respectively. The C had significantly higher phosphorus and potassium but lower value of TN than any of the formulations; it is also rich in carbon content among the formulations. Considering the levels of heavy metal in the FOFs, Iron (Fe) dominated the contents of all the formulations; it was significantly higher in AB compared to any other fertilizers and rock-based fertilizer contained the lowest quantity of Fe (Figure 4). Zinc was also found higher in compost and organic mixture than any other formulations. Generally, all the FOFs had low quantity of other heavy metals apart from Fe and Zn. There was no significant difference in the nutrient composition of the compost fortified with different nutrient-rich organic materials when compared to chemical fertilizer.

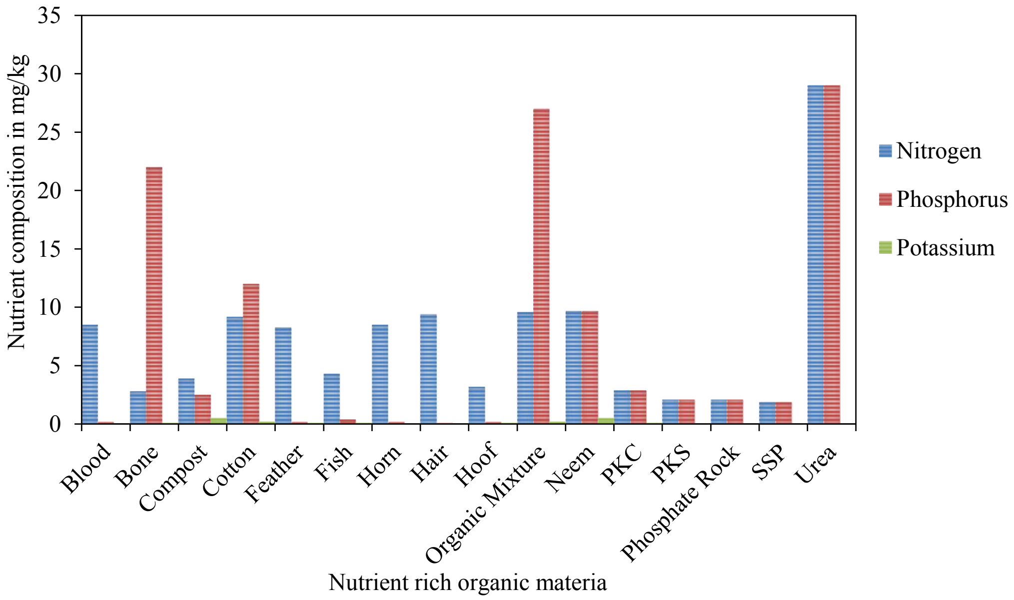

Figure 1. Nutrient composition of organic-rich materials

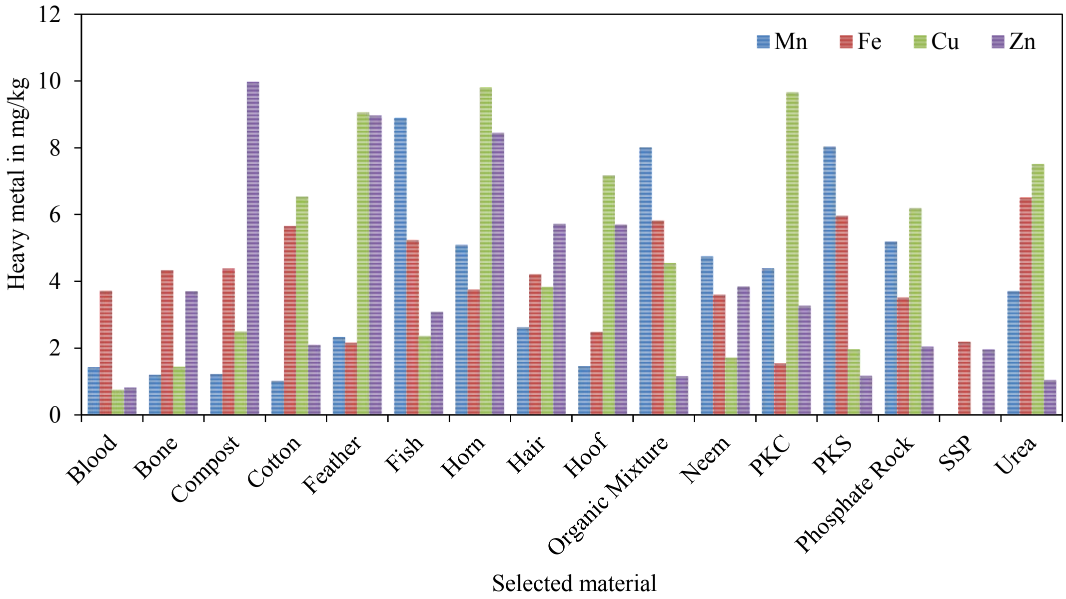

Figure 2. Heavy metal composition of organic-rich materials

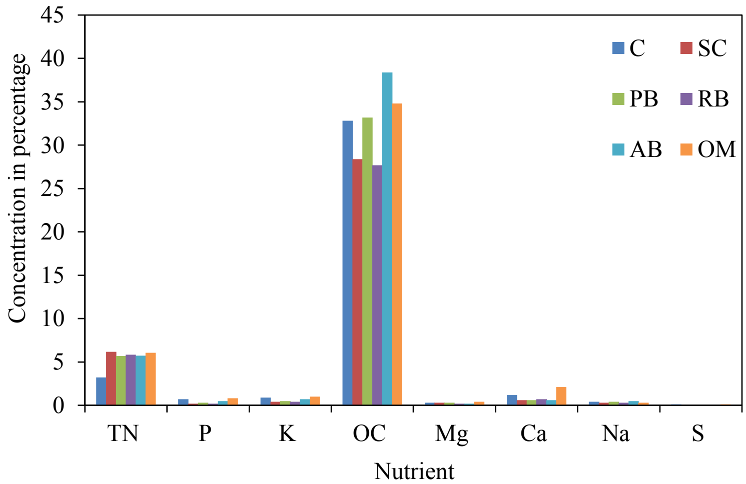

Figure 3. Nutrients composition of fertilizer (formulation) (Legend: C-Control; PB-Plant-based fertilizer; AB-Animal/Human-based fertilizer; RB-Rock-based fertilizer; OM-Organic-based fertilizer (Mixture of PB, AB, and RB); and, SC-Synthetic chemical fertilizer).

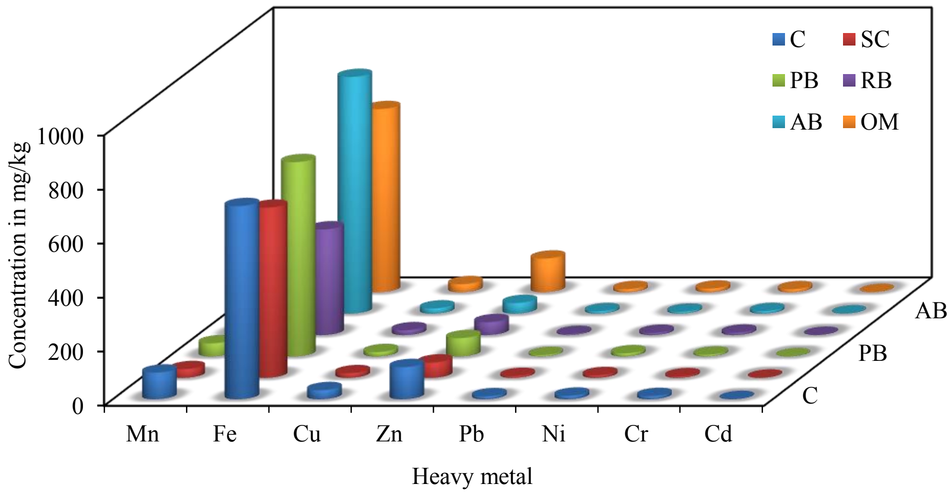

Figure 4. Heavy metal composition of fertilizer (Legend: C-Control; PB-Plant-based fertilizer; AB-Animal/Human-based fertilizer; RB-Rock-based fertilizer; OM-Organic-based fertilizer (Mixture of PB, AB, and RB); and, SC-Synthetic chemical fertilizer).

3.2 Effect of fertilizer on the agronomic parameters of crops

The effect of fertilizer formulations on the agronomic parameters of maize, soybean and yam are indicated in Tables 2, 3 and 4. The test crops were formulation specific as different crops were selective in their positive responses to different FOFs. There were significant differences at two weeks of application for all the crops (p=0.05) and much more significant effects were noted at maturity. That is, all the fertilizers showed direct relationship pattern to the agronomic parameters from germination to the maturity. However, there was no indication that any of the fertilizers had effect on the stem girth of yam. The SC showed highest effect only in soybean plant height as at first week after the fertilizer application (13.9±5.4 cm). Specifically, OM and RB for maize [NL (10.0±1.1; 9.2±1.0), PH (23.9±5.4 cm; 22.7±3.6 cm), SG (2.2±0.4 cm; 2.2±0.4 cm), LA (2.7±0.1 cm^2; 3.4±0.7 cm^2)]; AB and RB for soybean [NL (20.3±10.1; 15.3±4.5), PH (12.0±3.5 cm; 10.8±5.8 cm), SG (0.4±0.1 cm; 0.4±0.1 cm), LA (21.0±15.7 cm^2; 18.7±7.2 cm^2)] and RB for yam [PH (44.0±24.0 cm); SG (0.8±0.1 cm)] respectively gave the best crops' performances in agronomic parameters among all the formulations and the control. Apart from crops being selective to FOFs, agronomic parameters were similarly found to be formulation specific. This means that an agronomic parameter showed better performance while applied with a specific formulation. The following formulation and agronomic parameters specificities were found among the crops: Maize: (PH-OM; NL-OM; SG-RB; LA-RB), Soybean: **(**PH-SC; NL-AB; SG-AB; LA-RB), and Yam (SG-RB; LA-RB).

Table 2. Effect of fertilizer on the agronomic parameters of maize (Mean±SD, n=9)

Agronomic parameter	Treatment						F value	P value
	C	SC	PB	RB	AB	OM		
After 2 weeks of application								
Plant height	16.4±4.9^{a}	16.7±6.6^{a}	11.8±4.1^{a}	22.7±3.6^{b}	22.8±4.1^{b}	23.9±5.4^{b}	8.8	*0.0
Leaf area	2.0±1.0^{ab}	1.4±0.6^{a}	2.14±0.1^{abc}	3.4±0.7^{d}	2.9±0.1^{cd}	2.7±0.1^{bcd}	4.9	*0.0
Stem girth	1.2±0.5^{ab}	1.5±0.3^{a}	1.7±0.6^{b}	2.2±0.4^{c}	2.2±0.4^{c}	2.2±0.4^{c}	9.8	*0.0
No. of leaves	6.3±1.5^{a}	6.3±1.6^{a}	8.3±1.9^{b}	9.2±1.0^{bc}	8.8±1.2^{bc}	10.0±1.1^{c}	10.7	*0.0
At maturity (12 weeks)								
Plant height	218.2± 28.5^{a}	274.2± 30.6^{b}	284.9± 18.7^{bc}	313.6± 17.0^{bc}	301.8± 5.2^{bc}	326.9± 18.1^{c}	6.8	*0.0
Leaf area	4.4±0.2^{a}	5.7±0.2^{bc}	5.3±0.0^{b}	6.5±0.4^{c}	5.8±0.2^{bc}	6.2±0.1^{c}	6.9	*0.0
Stem girth	2.1±0.5^{a}	2.4±0.2^{ab}	2.4±0.4^{ab}	2.8±0.4^{b}	2.6±0.4^{b}	2.6±0.4^{b}	6.0	*0.0
No. of leaves	12.4±1.2^{a}	12.8±1.6^{ab}	14.2±2.4^{bc}	14.9±1.5^{cd}	14.2±1.2^{bc}	15.9±1.2^{d}	3.5	*0.0

Different letters (a, b, c and d) indicate significant differences along the rows
*Significant at p=0.05; KEY: Plant height (cm); Leaf area (cm^2); Stem girth (cm)

Table 3. Effect of fertilizer on the agronomic parameters of soybean (Mean±SD, n=9)

Agronomic parameter	Treatment						F value	P value
	C	SC	PB	RB	AB	OM		
After 2 weeks of application								
Plant height	9.6±3.0^{ab}	13.9±5.4^{b}	12.0±4.8^{ab}	10.8±5.8^{ab}	12.0±3.5^{ab}	8.9±4.7^{a}	1.4	*0.0
Leaf area	10.6±4.8^{a}	17.0±8.4^{a}	17.0±12.1^{a}	18.7±7.2^{a}	21.0±15.7^{a}	12.4±7.4^{a}	1.4	0.3
Stem girth	0.3±0.1^{a}	0.4±0.1^{a}	0.4±0.1^{a}	0.4±0.1^{a}	0.4±0.1^{a}	0.3±0.1^{a}	1.4	0.3
No. of leaves	11.2±5.6^{a}	17.3±8.6^{ab}	14.1±8.7^{ab}	15.3±4.5^{ab}	20.3±10.1^{b}	10.2±4.9^{a}	2.3	*0.0
At maturity (12 weeks)								
Plant height	51.8±6.6^{a}	53.7±7.0^{a}	51.7±5.6^{a}	55.6±6.0^{a}	53.4±11.7^{a}	53.5±6.7^{a}	0.3	0.9
Leaf area	40.0±8.8^{a}	44.1±10.8^{a}	47.3±9.5^{ab}	57.5±15.1^{b}	46.8±7.4^{ab}	46.7±11.7^{ab}	2.6	*0.0
Stem girth	0.7±0.1^{ab}	0.8±0.1^{b}	0.7±0.1^{ab}	0.7±0.1^{ab}	0.7±0.1^{ab}	0.6±0.1^{a}	2.5	*0.0
No. of leaves	70.1± 24.7^{a}	98.0± 27.6^{ab}	86.7± 35.5^{ab}	110.1± 33.2^{b}	98.8± 37.7^{ab}	71.8± 20.0^{a}	2.5	*0.0

Different letters (a, b, c and d) indicate significant differences along the rows
*Significant at p=0.05; KEY: Plant height (cm); Leaf area (cm^2); Stem girth (cm)

Table 4. Effect of fertilizer on the agronomic parameters of yam (Mean±SD, n=9)

Agronomic parameter	Treatment						F value	P value
	C	SC	PB	RB	AB	OM		
After 2 weeks of application								
Plant height	21.7± 24.3^{ab}	13.0± 10.1^{a}	13.9± 11.2^{a}	44.0± 24.0^{b}	19.0± 15.5^{a}	15.3± 23.6^{a}	2.2	*0.0
Stem girth	0.8±0.0^{cd}	0.7±0.1^{bcd}	0.4±0.3^{ab}	0.8±0.1^{d}	0.4±0.3^{abc}	0.2±0.4^{a}	5.1	*0.0
At maturity (12 weeks)								
Plant height	67.5±9.7^{a}	58.3±13.0^{a}	70.4±9.5^{a}	65.8±3.1^{a}	69.5±7.1^{a}	83.2±13.6^{b}	4.0	*0.0
Stem girth	0.8±0.2^{a}	1.0±0.2^{a}	0.9±0.1^{a}	1.0±0.1^{a}	1.0±0.1^{a}	1.0±0.1^{a}	0.9	0.5

Different letters (a, b, c and d) indicate significant differences along the rows
*Significant at p=0.05; KEY: Plant height (cm); Leaf area (cm^2); Stem girth (cm)

3.3 Effect of different rates of application on the test crops

The effects of different rates of AB application on agronomic parameters of maize and soybean are indicated in Figure 5. Also, the effects of different rates of RB application on maize, soybean and yam are shown in Figure 6. The AB formulation greatly increased the plant height of maize at 2.0 ton/ha while RB formulation enhanced the maize plant height mostly at 2.5 ton/ha. The RB formulation gave best performance on the soybean number of leaves and the leaf area when applied at 2.5 ton/ha. Apart from type of FOFs, another major factor that affected the plant growth was rate of application of FOFs, indicating that plant growth performance also depended on rate of fertilizer application.

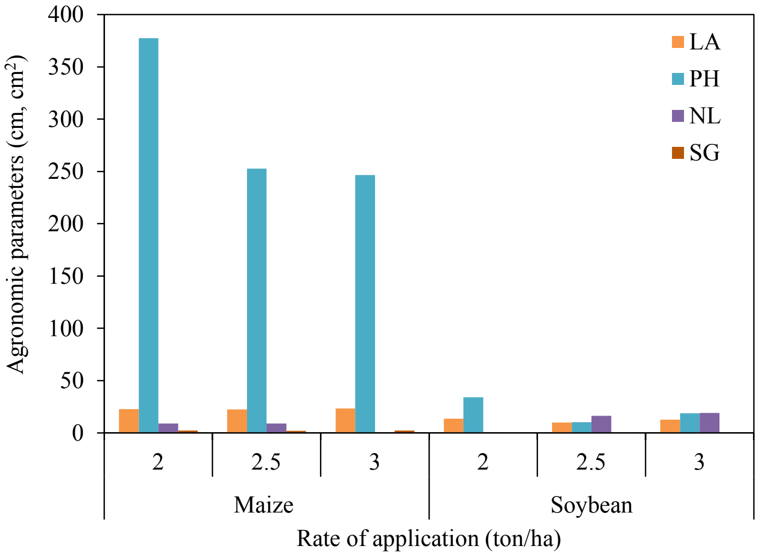

Figure 5. Effect of different rate of application of RB on agronomic parameters of the test crops (Legend: Plant Height, Leaf Area, Stem Girth, No. of Leaves).

4. DISCUSSION

4.1 Chemical composition of samples

The soil taken from the farm plot had low nitrogen content due to a high level of sand and low level of silt contents that are usually rich in humus and natural source nitrogen in the soil. This is an indication of no interference of nutrients (NPK) from their background levels in the soil that could have resulted from humus and loamy soil. The capacity to produce plant biomass remains an essential function of the soil productivity. Among all the fortifiers, blood and bone had the least quantity of heavy metals: Lead, Manganese, Nickel, Zinc, and Cadmium; and highest concentration of Iron. This could be due to the fact that animals (including humans) have threshold levels of these chemicals beyond which they may not survive (Veeken and Haneters, 2002). In addition, Fe is a major component of food taken by animals. Li et al. (2007) stated that application of organic matter increases concentration of Fe in the soil. In this study, all the fortifiers increased nutrients of the organic fertilizer after the fortification, with reference to macro nutrients: carbon, nitrogen, phosphorus, and potassium.

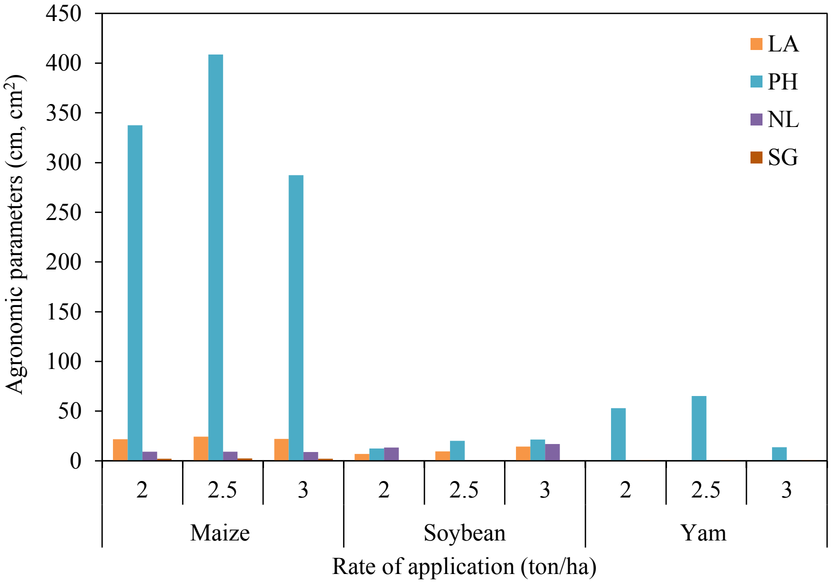

Figure 6. Effect of different rates of application of RB on agronomic parameters of the test crops (Legend: Plant Height (PH), Leaf Area (LA), Stem Girth (SG), No. of Leaves (NL)).

The primary nutrients required by microorganisms for growth are C, N, P, and K (Tchobanoglouse et al., 1993). The C and N play the most important role in the composting process: C is used by microorganisms for energy and growth while N is needed for protein and production (Metcalf and Edd, 2003). Neem and horn, among the fortifiers, had the highest quantity of Cu while the presence of high Cu content in the compost confirmed its high molecular weight humic acid, generally found in soil with well-decomposed organic matter (Prechthai et al., 2008) and which reduces the bioavailability of the heavy metals and their toxicity in plant (Inaba and Takenaka, 2005). The similarity in the nutrient composition of the organic fertilizer fortified with different nutrient- rich organic materials (FOFs) and chemical fertilizer is a clear indication of such effectiveness of fortification which raised the nutrient composition of the organic fertilizer to the status of synthetic chemical fertilizer. This observation corroborates with Mayer et al. (2008), Bouis et al. (2011), and Thavarajah and Thavarajah (2012). Also Fang et al. (2008) reported that the goal of compost fortification is not only to increase yield of crops and their qualities, but also to meet the demand for minerals required by humans. In composting process, Zn and Pb are significant contaminants and could have been responsible for the highest level of Zn noticed in the organic fertilizer. Likewise, Mariachiara et al. (2005) reported that at the end of composting process the concentration is 2.6 times the initial value for Zn and 1.6 times the initial value for Pb. Application of compost increased Mn, Cu and Zn contents of the soil but lowered Fe content (Courtney and Mullen, 2008). Several high revenue food crops such as beans, citrus, corn and rice are highly susceptible to Zn deficiency and bio-fortification is considered as a promising method to accumulate high content of Zn especially in grains (Christos et al., 2018), making the types of fertilizers used in this study more advantageous to plant growth.

4.2 Effect of fortified organic fertilizers on the agronomic parameters of crops

The FOFs generally improved agronomic parameters of the test crops, though selectively. In an experiment conducted by Ayoola and Makinde (2008) to assess the growth and yield of maize applied with nitrogen-enriched with cow dung, the plants were comparable in height and leaf area with those grown with inorganic fertilizer. Application of organic fertilizer improved growth and yield of bean plants compared with those amended with mineral fertilizer (Fernandez-Luqueno et al., 2010). The results of FOFs' performances obtained in this study are in agreement with findings of Francesco and Lionello (1992) who tested effects of compost fortified with organic and inorganic materials on agronomic parameters of maize. They concluded that growth responses to inorganic fertilizers do not provide better performance. The reasons for the FOFs being selective on the type of crop and agronomic parameters could be associated with different chemical forms of nutrients in the fortifiers and genetic factors of test crops. In selecting any type of the FOFs, one should consider which part of a plant is better prioritized: leaf area, plant height and so on. In contrary, Sajal et al. (2018) observed that the agronomic parameters of grain and straw did not differ significantly among the organic amendments. Maize stem girth generally reduced at maturity and the maize number of leaf was constant at the appearance of husk because growth of the plant had stopped. All FOFs performed better than synthetic fertilizer in number of leaves. This finding is not in agreement with that of Olubunmi et al. (2011) who reveals that increase in relation to number of leaves of *Corchorus olitorus* are in order of NPK>poultry manure>cow dung>urea.

4.3 Effect of different rates of fortified organic fertilizers application on the crops

Type of FOFs and rate of application were major factors that affected the plant growth. Kolade et al. (2005) indicated that the composts could be applied to maize at 4 ton/ha to obtain yields comparable to those of organo-mineral fertilizer and chemical fertilizer which are popular among Nigerian farmers. Bolanle et al. (2010) found application of NPK fertilizer gave a lower yield of maize (5.40 ton/ha) to that of organo-mineral fertilizer (6.06 ton/ha) when applied at a rate of 6 ton/ha. The lower rate (2.0 and 2.5 ton/ha) of application with enhanced agronomic performances observed in this study indicated that the FOFs were better than fortified composts used by the previous researchers (Kolade et al., 2005; Bolanle et al., 2010; Rady et al., 2016). The rates were also far below poultry manure (10 ton/ha) and cow dung (ton/ha) utilized by Olubunmi et al. (2011) when compared the effect of poultry manure, cow dung, NPK 20:10:10 and urea fertilizers on growth, nutrients content and yield of *Corchorus olitorus* and *Celosia argentina*. Also, Yang et al. (2011) found that the best growth performance was recorded by application of 40 ton/ha organic fertilizer which does not match up with effectives rate of FOFs utilized in this study.

Very similarly, Sutharsan et al. (2016) showed that different rates of nitrogen and phosphorous had significant increases in plant height, leaf area, plant dry biomass as well as root nodulation of soybean when applied with 50N:125P:75K kg/ha. Also, performances of FOFs are in consonance with findings of Roba (2018) who assessed the effect of mixing organic with inorganic fertilizer on soil fertility and productivity. The study revealed that appropriate application of organic with inorganic fertilizers increases the productivity without negative effect on yield quality and improves soil fertility than the values obtained by organic or inorganic fertilizers separately.

5. CONCLUSION

The composted market organic waste, fortified with nutrient-rich naturally available materials, performed better than the organo-mineral fertilizer on agronomic parameters of the three crops (maize, soybean and yam). The implication of this is that ordinary organic fertilizer can be fortified with nutrient-rich natural materials and applied at low rate of 2 ton/ha. This process facilitates desired growth performances of the three crops comparable to those of organo-mineral fertilizer and chemical fertilizer (NPK) which are popular among Nigerian farmers. Different fortified organic fertilizers influence the crops differently, and in selecting any of the fertilizers for a certain crop, the part of a plant (leaf area, plant height and others) to be considered is very important. Thus, OM and RB are recommended for maize; AB and RB for soybean; and RB for yam. The study recommends another study focusing on the effect of seasonal variation on effectiveness of organically fortified fertilizers, using the three test crops.

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