Earthworm Activities in Two Contrasting Diets and Nutrient Content of the Cast Produced: It's Efficiency in Comparativeness to Traditional Compost on a Deficient Loamy Sand Soil and Soybean Yield

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DOI: https://doi.org/10.51584/IJRIAS.2026.11060205

Received: 17 June 2026; Accepted: 22 June 2026; Published: 09 July 2026

ABSTRACT

Earthworms have been found to be very efficient in biodegradation, nutrient release and recycling. Thus, in this study the comparative effectiveness of five composts in improving the productivity of degraded loamy sand soil was investigated for 2 years with detrimental effects in a greenhouse study. Traditional Bracharia compost (TBA); traditional Bracharia-Eupatorium compost (TBUA); worm worked Bracaharia compost (WBA) and worm worked Bacharia-Eupatorium compost (WBUA) and control (CO). The five (5) composts for the 2 years under study showed significant ($P < 0.05$) difference in most of the parameters studied with increased value in 2023-year planting relative to 2024-year study. Worm worked composts enriched the soil with nutrients and supported soybean growth and yield more than the traditional composts. The ranking of the soybean yield increase and residual effect in 2024 year planting respectively were; WBA > WBUA > TBUA > TBA and WBUA < TBUA < WBA < TBA < CO. Enhancement levels of plant nutrients and soil pH are evident that the composts studied have a high fertilizing value with good potentials for restoration of productivity of degraded loamy sand soil. The composts enriched soybean root and shoot with heavy metals but below their critical level for humans and animals health.

Keywords: Earthworm, fertility reclamation, food security, mineralogy, microbes, microbial biomass

INTRODUCTION

With rapid increase in population, there is every need that food increase should follow the same pace to address the food demand. But land available for crop production are limited arising from urbanization and environmental degradation. Also, wastes have increased astronomically beyond local authorities due to population increase and rapid industrialization. The odour from the wastes are sickening and adds to the spread of diseases which affects labour productivity. This has made efficient management of the organic waste that has become an eye sour across the cities in Nigeria a problematic and a very rigorous affair. In fact, efficient disposal and management of organic wastes has become a burden to the government. But a healthy environment is dependent on sustainable approach and cost-effective manner in handling waste disposal as observed in Mba (1983;1996) and Nweke et al 2020ab. Uncontrolled disposal of solid wastes causes environmental hazards, soil and water pollution, pests, disease and rodents spread that cause sickness and inconvenience to the populace. Some even dump the refuse in a drainage channel leading to the blockage and when rainfalls the entire refuse are brought out on the road by the flood making the road unpassable by the commuters, even to the destruction of some structures. Thereby increasing economic cost, pain, burden and in extreme case death. A well organized and managed solid wastes disposal can be a source of revenue to the government and local authorities. So beside dumping and land filling that may not attract economic value to the government, solid wastes disposal can be carried out efficiently and effectively by earthworm composting popularly known as vermicomposting through vermiculture (Mba 1996; Pandey et al., 2006; Samaranayeke and Wijekoon 2010; Nweke et al., 2019; 2020a). Meaning that solid organic wastes of all types can be used to raise (breed) worms, while the wastes in itself are converted to earthworm casts. The vermicompost that is virtually earthworm casts produced from the organic wastes is high valued soil ameliorant product as it contains plant available water stable nutrients. It is biologically active as it contains plant hormones and polycyclic aromatic hydrocarbon that can provide other advantages. The generated casts can be marketed to farmers, gardeners, or landscape industry for use in landscape plantings or for market gardens for use as a compound of potting soil mixes. The earthworms themselves can be sold to fish farmers, fish hatcheries, classroom biology teacher etc. or further processed to become feed supplement in livestock. Through all these ways money comes into the government pocket and adequate employments are created for the teaming youth population. Thus, organic waste fed to earthworms result in to money, biomass and excellent vermicompost product. Note there are ministries of Agriculture and national resources as well as solid wastes management board across every state in Nigeria, so if the will is there, then this vermiculture a well-organized biotechnology can be put into use for adequate wastes disposal for the well-being of the society and sustainable environment. Earthworms being omnivorous thrive best on garbage pile and manure heaps. Their vermicomposting decomposes, organic wastes many folds faster than merely microbial decomposers. They are noted to be natural bioreactors, they redesign biological and physicochemical features of soil and the entire ecosystem. Through their burrowing activities in conjunction with vermicomposting, soil material mixing and distribution activities contribute immensely to enhance soil physicochemical and biological properties. Thus, impact healthy environment, soil water resources and ecological harmony.

Nigeria is highly blessed with potentially resourceful efficient and versatile earthworm species which can adequately address food security, water management, soil and environmental bioremediation and productivity sustainably. Hence there is need to develop appropriate biotechnology strategies using earthworm potentials to address Nigerian solid waste management, food security and environmental management. Note that thermophilic (anabolic) digestion and conventional compositing produce methane and harmful gas and foul odour of which is not with vermicomposting, so workers on vermicomposting are healthy free. Nweke (2013; 2017), Nweke et al. (2020) documented work on the earthworm activities, vermiculture, vermicompost production, detoxification and improvement of soil fertility and crop yield. The earthworm (Nigeria *Eudrilus spp*) was found to detoxify cassava peel of cyanide poison, enhanced soil water holding capacity and nutrient availability. Thus, the objective of this study is to evaluate the activities of *Eudrilus eugenae* earthworm on two contrasting diets, nutrient content of the casts and comparative effectiveness of worm worked composts and traditional composts on degraded loamy sand soil and soybean yield. In order to effectively achieve the objective, the following among other things will be critically evaluated;

- Composts and cast production and their nutrient release
- Their biodegradation and pollution potentials in terms of heavy metal contents
- Their immediate and long-term effect on the degraded loamy sand soil
- Their immediate and residual effect on soybean yield.

MATERIALS AND METHODS

In this study *Bracharia spp* and *Chromolaena odorata* formerly *Eupatorium odoratum* were composted with animal manure in order to produce bio-fertilizer soil amendments. *Chromolaena odorata* grows rapidly, branches and cover extensive areas. In this form it kills young weeds growing under it and concentrates moisture in the soil. A source of organic materials in soils where it is growing. The plant has characteristic pungent smell and as such unpalatable to sheep, goat and cattle. Therefore, these livestock try to avoid it. In rice production, it is often regarded as soil fertility indicator especially after the rain, and the water have established. Among the local people, and rural dwellers, the weed plant when mashed can be used in treating scratch and wound due to its anti-inflammatory, antimicrobial and antioxidant properties. *Bracharia spp* grass in its own case is a perennial grass, its creeping ability help in the killing of young weeds growing underneath and concentrate moisture in the soil. The grass is of good quality pasture to the livestock as it can be prepared into silage or hay. Unlike the *chromolaena odorata*, the goat, sheep, cattle and even rabbit eat the grass. The grass has highly competitive vigor. It enriches the soil whereby the decomposition of leaves and other organic residues release substantial number of nutrient elements.

Animal materials and mixtures

The organic wastes, pig and poultry were collected from piggery and poultry section of the Animal Science Department of University of Nigeria Nsukka farm. Pig droppings were mixed with poultry droppings on fresh dry basis to form animal manure designated as A. 60g each of animal manure (Pig and Poultry) and 30g each of grass residue (*Bracharia* and *chromolaena*) on fresh weight basis was used to determine the dry matter yield of each compost material before composting.

The animal mixture is in the proportion of 1kg pig: 2kgpoultry = Animal manure (A).

Compost mixture and quantity

Compost BA: *Bracharia* + Animal manure

10kg animal manure (A):10kg *Bracharia* grass (B). Total or quantity = 20kg BA (Compost)

Compost BUA: *Bracharia* grass + *Eupatorium odoratum* + animal manure

Quantity: 10kg animal maure:8kg Bracharia grass:2kg Eupatorium residues = 20kg BUA (Compost)

Where; B = *Bracharia* grass,

U = *Eupatorium odoratum*

A = Animal manure

The major component of the study

Green house study

- Decomposition study (traditional composting)
- Earthworm production and worked compost study (worm worked compost)
- Soybean production

Green house study

Traditional compost (TC) preparation

Two composts made of *Bracharia* grass plus animal manure (BA) and *Bracharia* grass plus *Eupatorium odoratum* (*Chromolaena odorata*) plus animal manure (BUA) mixed thoroughly respectively were composted following the procedure already described in an earlier study (Nweke, 2013; 2014; 2017; 2019)

Earthworm (*Eudrilus eugenae*) production and Worm worked compost (WC)

850g each of the BA and BUA composted was aerated 24hours and moistened overnight and placed in four (4) perforated plastic baskets of uniform size and diameter for each compost type. Five (4) sub-adult earthworms were weighed collectively and inoculated in each basket containing the compost. The experiment was laid out

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

in a completely randomized design (CRD) and replicated four (4) times. Each of the experimental type were covered with polythene sheet and stacked together. The principles outlined by Nweke (2013) were followed to maintain moisture level, avoid CO_2 build up and to protect the worms from predators. After seven weeks and 5 days of inoculation the worms were harvested by hand sorting and collectively weighed per basket. The cast produced were collectively weighed per basket and taken to the laboratory for both physical and chemical analysis.

Soybean production

Immediately after the earthworm harvest another experiment was set up with the worm worked compost (WC) and the traditional compost (TC) to determine their comparative effectiveness in improving the productivity of nutrient deficient loamy sand soil of southeast, Nigeria and soybean yield for 2 years study. The composts are designated as

TBA and TBUA for traditional compost (TC)

WBA and WBUA for worm worked compost (WC)

CO control with no compost application

500g each of TBA; TBUA; WBA and WBUA respectively were weighed out and mixed thoroughly with 10kg soil and laid out in a completely randomized design (CRD) and replicated four (4) times. Five soybean seeds dressed with distilled water were planted per pot. After germination the stands were thinned down to three (3) stands/pot. At the end of the eight (8) weeks and six (6) days agronomic parameters and soybean yield were measured.

Residual effect study

The above was repeated without further addition of composts to test the residual effect of the traditional compost (TC) and worm worked compost (WC) on soybean growth and yield.

Laboratory Study

Compost (Traditional compost)

Dry matter yield of compost: 30g on fresh weight basis in 4 replicates was used to determine the dry matter yield of each compost using the formula;

Dry matter% = $\frac{\text{oven dry weight}}{\text{fresh weight}} \text{x } 100$

Aggregate stability of Compost: 10g fresh weight in 4 replicates was used to determine the aggregate stability status of each compost using the formula;

Aggregate Stability % = $\frac{\text{weight of WSA}}{\text{weight of sample}} \text{x } 100$ (Because sand is not involved)

Moisture content: 20g fresh weight in 4 replicates was used to determine % moisture content of each compost.

% moisture content = $\frac{oven\ dry}{fresh\ weight}\ x\ 100$

Compost water retention or holding capacity: 30g fresh weight in 4 replicates was used to determine the water retention capacity of each compost using the formula: Moist weight of compost – oven dry weight of compost.

Weight and water loss of compost are calculated using the formula;

% weight loss = sample weight – composted weight x100

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

% total weight loss = sample weight – air dry composted weight x 100

% water loss of compost on fresh basis = fresh weight after composting – weight after air drying of the compost x 100

% degree of decomposition = $\frac{weight\ of\ compost\ sample - fresh\ weight\ after\ composting}{weight\ of\ compost\ sample - weight\ of\ compost\ after\ air\ drying}$ x100

Compost decomposition rate and half life

The rate of the decomposition of the composts were determined using Gilmour et al. (1977) equation

$K = \frac{2.303}{t2 - t1} x\ log C1/C2$

Where; K = Compost

C1 = dry matter at the start of the compost (t1)

C2 = dry matter at the end of the compost (t2)

t2 –t1 days the compost lasted

while the half-life of the compost was calculated using the equation

$T50 = \frac{IN\ (0.50)}{K} = \frac{0.693}{K}$

Earthworm cast analysis (worm worked compost)

Physical parameters

Bulk density of cast (BDc): This was calculated using the formula

BDc = $\frac{\text{mass of cast}}{\text{volume of cast}} gcm^{-3}$

Dry matter yield of the cast (DMc): 5g fresh weight of cast in 4 replicates was used to determine the dry matter percentage of the cast using the formula;

DMc % = $\frac{\text{oven dry weight}}{\text{fresh weight}}$ x 100

Water retention (retained or absorbed): 10g fresh weight of cast in 4 replicates was moistened to field capacity and then oven dry to determine the water retention capacity of the cast, using the expression;

Moist weight of cast – oven dry weight of cast

Aggregate stability: 5g fresh weight of cast in 4 replicates was used to determine the aggregate stability of the cast using the formula;

Aggregate Stability = $\frac{\text{Treated cast}}{\text{untreated cast}}$ x 100

Where; treated cast = cast sieved through 0.25mm sieve

Untreated = cast not sieved

Chemical parameters

Cast and Soil

The pH 1:2.5 solid to liquid ratio was determined in water, Walkley and Black (1934) was used to determine the OC content. Total nitrogen (TN) was analyzed using the procedures as described by Adepetu (1990). Available P was determined by the method of Bray and Kurtz (1945). Buffer capacity and electrical conductivity (EC) was determined by using an aqueous solution of Ca $(OH)_2$ and then a solution of dilute H_2SO_4. Soluble mineral cation was determined electrically using digital conductivity meter in 1: 2.5 soil: water ratio. Exchangeable basic cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted in 1N NH_4OAC at pH 7 and calcium and magnesium determined using atomic absorption spectrophotometer, potassium, and sodium determined using flame photometer. Cation exchange capacity (CEC) was determined by the unbuffered barium chloride ($BaCl_2$) method of Nikol (1959). Total exchangeable acidity (TEA) was estimated titrimetric, while percentage base saturation (%BS) was estimated using the formula;

$$\% \text{ BS} = \frac{TEB}{CEC}\ x\ 100$$

Soil physical parameters

Silt + clay dispersion was determined using the method of Nkidi-Kizza et al. (1984). Bulk density (BD) was determined using core method as described by Carter (1990), while total porosity (TP) was estimated from bulk density (BD) and particle density (PD) thus:

$$\text{TP} = \left(\text{I} - \frac{\text{Pd}}{\text{Pd}}\right) \text{x } 100$$

Where BD = Bulk density

PD = particle density

Mean weight diameter (MWD)

$\text{MWD} = \sum_{i=1}^{n} \text{x i wi}$ i.e. the sum of the product of means xi of each size grade and proportion of the total sample weight wi of each size grade.

Geometric mean diameter (GMD) was calculated using the formula below;

$$\exp\left(\sum_{i=1}^{n} \text{wi} \log 10 \text{ Xi}\right)$$

Where; n = number of aggregate fractions under wet sieving,

x_i = mean diameter (mm) of aggregate fraction 'i' under wet sieving

w_i = mass proportion of aggregate fraction under wet sieving.

Soil moisture content (MC) was estimated using the formula;

$$\% \text{ MC} = \frac{mass\ of\ soil\ at\ saturation}{oven\ dry\ mass\ of\ soil} \text{ x } 100$$

Saturated Hydraulic conductivity (Ksat) was determined by the modified constant water head methods of Klute (1986).

Water stable aggregate (WSA) was determined using the wet sieving techniques of Kemper and Chepil, (1965) and then estimated using the formula below;

$$\text{WSA} = \frac{Ma+s-Ms}{Mt-Ms}\ x\ 100$$

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

Where;

Ma+s = mass of the resistant aggregates plus the sand fraction (g)

Ms = Mass of the sand fraction alone (g)

Mt = Total mass of the sieved soil (g)

Biological parameters

Soil microbial biomass was estimated using the method of Stotzky (1965), water soluble OC by the method of Mazzarino et al. (1993), microbial biomass C and N was measured with chloroform fumigation extraction method of Anderson and Ingram (1993). While dilution plate method with suitable media was used to estimate the total population of Bacteria, Actinomycetes and Fungi counts and number of colonies forming units (CFU) expressed as $CFUg^{-1}$

Heavy metal determination

Atomic absorptiometry after digestion with conc. HNO_3 was used to determine the content of Fe, Zn, Cu, and Pb while B was determined by hot water extraction method.

Agronomic Parameters studied

Plant height and leaf area was measured with tape, number of nodules by counting, weight of nodule by weighing using digital weighing balance. For root length measurement, the treatments were moistened to saturation to enable the roots to be pulled out without damage or cut. The roots were washed and measured with tape to get the length and then cut off from the base and weighed to get the fresh weight and then subjected to oven drying for 48hrs at 105^{o}C to get the root dry matter. The fresh shoot weight was weighed with digital balance and oven dry at 105 for 48hrs and then weighed again to get the shoot dry matter yield.

Fresh root density was calculated using the formula;

Fresh root weight density (FRWD) = $\frac{Mass}{Volume}$ gcm^{-3}

Where; M = is the fresh root weight (g); V = is the volume of the soil sample (cm^3)

Root to shoot ratio was calculated using fresh root and shoot weight i.e.

Root: Shoot = $\frac{Fresh\ root\ weight}{Fresh\ shoot\ weight}$

Soybean dry matter yield

Percentage dry matter yield increase over control was calculated using the expression;

$$\%Yi = \frac{YSt - YSc}{YSc} \times 100$$

Where;

%Yi = percentage yield increase

YSt = soybean dry matter yield in the treated soil

YSc = soybean dry matter yield in the control within each phase (1 and 2 planting year) of study

Percentage soybean yield reduction with time was evaluated;

$$\%YSr = \frac{YS1-YS2}{YS1}\ x\ 100$$

Where;

%YSr = percentage soybean yield reduction

YS1 = soybean dry matter yield in the first-year planting

YS2 = soybean dry matter yield in the second-year planting.

Residual effect of the treatments in the study on soybean was calculated using the expression

$$REt = \frac{YS2}{YS1} x\ 100$$

Where; REt = Residual effect of the treatment in the study, YS2 and YS1 are as defined above

Data Analysis

Data generated from the study were subjected to analysis of variance (ANOVA) in accordance to the procedure of completely randomized design (CRD) according to Steel and Torrie (1980) and significant differences among treatment means were separated using least significant difference (LSD) at 5% alpha level.

RESULT AND DISCUSSION

Initial properties before the beginning of the study

The physical parameters of the soil before the beginning of the study presented in Table 1a showed bulk density (BD) of the soil to be 1.316 gcm^{-3}, aggregate stability 57.87%, and water retention 5.403 respectively. The result suggests the soil to be fragile, non-cohesive, and lacks the ability to hold or retain water, meaning that nutrient solubility, recycling, transmission and uptake by plant will be difficult. The chemical nutrient showed the soil to be strongly acidic (4.70) and low in nutrient content. The value recorded showed the chemical nutrient to be below their critical level for crop production in the area. But their concentrations in poultry and pig and the compost BA and BUA (made from animal manure, *Bracharia* and *Eupathorium* residues) were higher (Table 1b). This simply implies that both soil and soybean plant will benefit when they are used as soil ameliorant.

Table 1a. Nutrient content of soil before commencement of the study

Property	Soil
Sand gkg^{-1}	850
Silt gkg^{-1}	50
Clay gkg^{-1}	140
Texture class (TC)	Loamy sand (LS)
pH H_2O	4.70
OC %	0.57
TN %	0.073

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

Avail. P mgkg^{-1}	8.5
ECEC cmolkg^{-1}	7.05
Ca cmolkg^{-1}	2.91
Mg cmolkg^{-1}	1.62
K cmolkg^{-1}	0.38
Na cmolkg^{-1}	0.29
Water retention	5.403
Aggregate stability %	57.87
BD gcm^{-3}	1.316
MB $MgCO_3^{-1}$	11.865
MBC mgkg^{-1}	65.367
MBN mgkg^{-1}	3.185
WSC %	3.48

BD = bulk density; ECEC = effective cation exchange capacity; MB = microbial biomass; MBC = microbial biomass carbon; MBN = microbial biomass nitrogen; WSC = water soluble organic carbon

Table 1b. Nutrient content of animal wastes and biofertilizer (BA and BUA) before worm inoculation

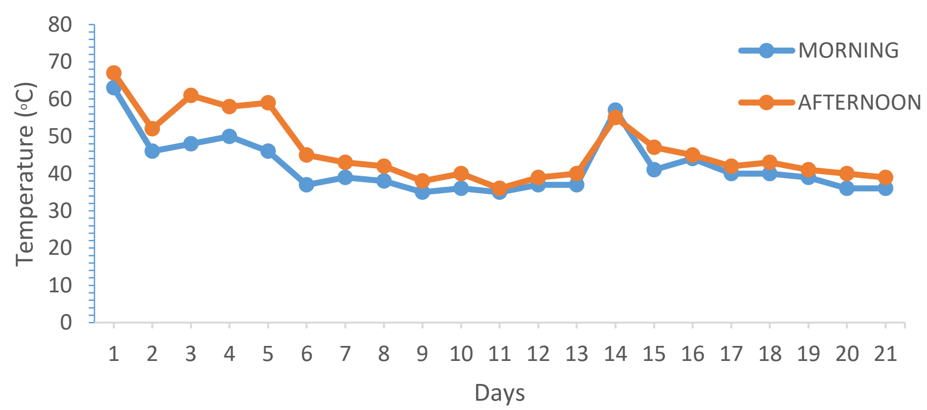
Property	poultry	pig	Bracharia grass	Eupatorium residue	Compost BA	Compost BUA
Dry matter	34.5	49.54	52.93	25.91		
pH H_2O					6.49	6.59
OC %	13.93	7.84			21.96	25.80
TN %	2.97	2.10			0.56	0.75
Avail. P mgkg^{-1}	22.68	10.99			16.09	18.52
ECEC cmolkg^{-1}					10.46	12.54
Ca cmolkg^{-1}	7.85	2.91			5.91	6.41
Mg cmolkg^{-1}	5.54	1.85			2.61	3.95
K cmolkg^{-1}	1.53	0.65			0.85	0.96
Na cmolkg^{-1}	0.72	0.44			0.51	0.45

Compost decomposition study and physical parameters of the compost

INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN APPLIED SCIENCE (IJRIAS)
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

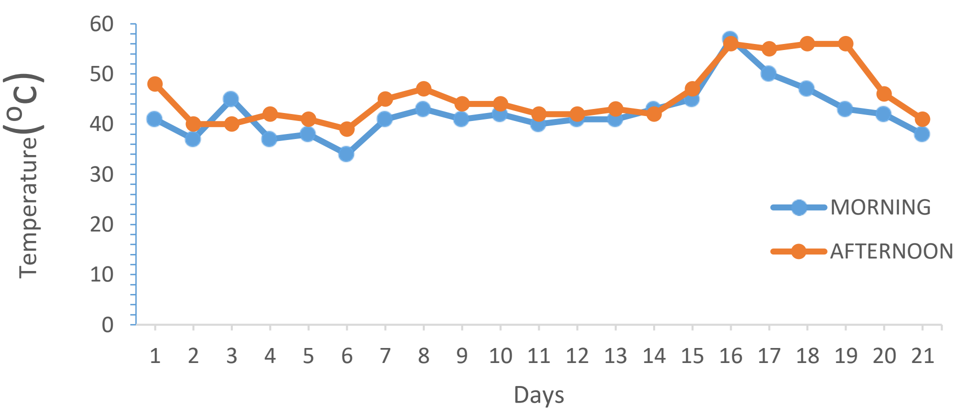
Temperature Reading

The figure 1 and 2 showed the result of temperature readings for BA and BUA composts decomposition study. The temperature of decomposition varied with the compost type; the rate of biodegradation was faster in the afternoon by the temperature reading recorded compared with morning reading. For BA compost the temperature was at its pick on the 1st day for both morning and afternoon but then decreased each day until the 14th day when the temperature rose again to 62°C and then decreased each day again until 21st day. The BUA temperature of decomposition for morning and afternoon at 1st day showed 40°C and 49°C respectively, but showed maximum pick of 52°C for morning and afternoon on 16th day of decomposition. After this, the morning temperature decreased rapidly as against the afternoon temperature, that rose again on 18th day and then decreased rapidly. The variations in temperature and rate of degradation among other things might depend on the type of microbes within the compost type (the most controlling factor due to their diverse population), particle size as the compost materials were chopped into pieces to create large surface area for chemical reactions, oxygen supply, pH and moisture content of the compost heap. The high temperatures recorded are ideal as it will help to destroy disease causing organisms within the compost pile. Further it will greatly influence the rate of enzymatic reactions within the microorganism. Nester et al. (2001), noted that the rate of enzymatic reactions in the cell doubles for each 10°C rise in temperature



Temperature for the decompositon of BA

Figure 1



Temperature readings for the decomposition of BUA

Figure 2

Decomposition study

The decomposition study and physical parameters of the composts were recorded in Table 2. The results showed that the two composts BA and BUA (traditional composts TC) differed significantly ($P < 0.05$). The decomposition rate constant $gday^{-1}$, weight loss and percentage rate of decomposition was highest in BA compared to their values obtained from BUA. The compost mineralization half-life was 39 days in BA and 37 days in BUA, meaning that it took 39 days and 37 days respectively for 50% of BA and BUA to be decomposed. Nweke et al. (2021) working with animal manure observed that it took poultry, swine and cow wastes, 25, 37 and 45 days respectively to decompose. The implication of the result is that mineralization rate was higher in BUA than BA of which indicates that BUA decomposed faster to release its nutrients than BA. The faster decomposition observed in BUA probably may be related to its nitrogen and carbon content. That is, it may have higher N content and lower C:N ratio, because high N content and low C: N ration enhance fast decomposition as there are inverse relationship between C: N ratio and the amount of N mineralized from organic wastes. Because changes in soil N status have been found out to alter the microbial community physiological profile based on individual C substrate utilization pattern (Grayston et al., 1998; Wadrop et al., 2000; Collins and Cavigelli, 2003; Paul et al., 2005). The difference in the decomposition result can equally be associated to amount, rate, and relevant thermophilic heterotrophic microorganisms present in each compost material mixture. As the microbial community composition, and microbial biomass differs and specific with plant type, and litter type. Materials with rapid microbial decomposition according to the study conducted by Parr et al. (1986), tend to release nutrients contained in them rapidly compared to those that are resistant to microorganism attack, hence release nutrients contained slowly. The addition of animal manure (Pig/Poultry) rich in microbial population as noted by Nweke et al. (2021), increased the decomposition process in both treatments particularly with, BUA. The decomposition studies result simply suggests that when BUA is used as soil amendment will mineralize easily releasing its nutrients in the soil. However, organic material that release nutrient contained in them slowly might prove distinct advantage in long term residual improvement in physical properties of soil. The economic implication when the composts are used in soil, increases yield of crops, promote growth of plant hormone, nutrient availability, reduced fertilizer cost, reduced emission of greenhouse gases, and leaching loses etc. The dry matter, aggregate stability, water holding capacity and water retention results were significant and varied with the compost type. Higher value in dry matter percentage and aggregate stability were recorded in BUA. While higher value in water holding capacity and retention were obtained from BA. The implication is that compost when used as soil amendment due to high OM content and heterogenous in composition will mix with soil mineral constituents to form stable soil aggregates, increase the ability of the soil to hold water and all that dissolve therein. Hence giving positive effect on water that is transmitted and retained in soil. This scenario will enhance nutrient release availability and recycling and increased crop yield on the soil. The main aim of compost as opined by Cooker (2006) is to obtain stable chemical and biological rich product with micro and macro nutrients. Soil application of different organic wastes have been reported (Mubarak et al., 2003; Nweke and Chime, 2021) to improve soil aggregation and water holding capacity of soils.

Table 2 Compost decomposition study and properties

Treatment	Dry matter %	Agg. Stability %	WHC %	Water absorbed or retained	%water loss	% total weight loss	Mineralization rate constant	Half life (days)	% Weight loss (g)	% rate of decomposition
BA	40.41±0.32	99.14±0.752	47.03±0.03	17.89±0.035	14.5	565	0.0177	39.153	278	86.25
BUA	45.52±0.88	99.17±0.591	43.08±3.36	16.35±0.046	17.5	650	0.0187	37.059	300	85.00

Effect of BA and BUA diets on *Eudrilus eugenae* activity and production

Earthworm production activities on BA and BUA diets are recorded in Table 3. The values varied with the diets and earthworm performance was better in BUA compared to the BA result. The survival rate of the worm indicated 64.03% in BUA as against 55.67% obtained from BA, while the results on weight of worm at harvest and weight of casts showed percentage increase of 16.6%, and 28.23% in BUA relative to BA. Pandey et al. (2006) under laboratory condition in 60 days study found food consumption, worm weight and cast production of *Octolasiun tyrtaeum* to have varied significantly with maize, grass and wheat diets. While Nweke et al. (2016, 2020) recorded an increased significant value in the above parameters with *Paspalum* and *Bracharia* grass, fruit and vegetable wastes respectively. Thus, infaring that earthworm is specific to plant species and passing through the gut their cast modified the plant species. Earthworm ingest litter materials and excrete nutrient rich casts, through this, they enhance nutrient availability and cycling, aeration, water infiltration and drainage. Also, through grinding and mixing litter materials by the help of substances secreted by the gut they enhance greatly the humification, fragmentation and size reduction of the organic waste diets, stimulate and modify microbial community in a diverse way. The preference of BUA to BA diet by the worms as shown by the results may be associated to any of the variables such as chemical composition of the diets, stage of the microbial transformation before inoculation, humidity and temperature variations of the diets, oxygenation and microbial activities within the diets, variations in salts and soluble substances of the diets. All these working together or in part may have contributed to the differences in result obtained. Generally, these have the capacity to affect the formation of humus, chemical properties of the casts and mobilization of plant nutrients.

Daily examination of the earthworm culture showed the worms to be very active on the two diets at the surface, middle and bottom of the cultures depositing their casts thereby affecting the decomposition rate and microbial composition. Cast an evidence of the worm adaptability to the diets and vigorous litter degradation were noticed exactly on the 4^{th} day after inoculation, but the period of notice varied with the cultures. Extensive casting was noticed on the morning of the 4^{th} day in BUA, while it was observed in BA at the evening of the same day because the cultures are being monitored morning and evening. Distinct degradation of the diets was observed 10 days after the earthworm inoculation but more on BUA compared to BA diet. This probably resulted in the higher weight of worm and cast production observed in BUA. Similar observations were made in 100 days studies of Nweke (2013) with *Andropogon gayanus* and *Bracharia* grass diets using *Eudrilus euganae*. The inclusion of animal manure in the diets enhanced earthworm diet decomposition, quality and quantity of casts produced in this study. The animal manure might have contained high nutrient digestible organic materials such as sugars, starches, cellulose etc. and optimum pH conditions for the *Eudrilus eugenae* activities. Thus, their inclusion influenced the weight of worms at harvest as earthworm weight increased 541.01% in BA and 658.39% in BUA relative to the initial weight of the worms respectively. In addition, studies have shown that the palatability, nature of diet, stage of fermentation of diet and rate of diet available, organic matter degradability, toxicity of diet, microbial diversity within the diet etc. influenced greatly the earthworm size, population/biomass, growth rate, weight, agility and fecundity (Kooch and Jalivand, 2008; Munnoli et al., 2010; Samaranayake and Wijekoon, 2010; Pathma and Sakthival, 2012; Nweke, 2013; Nweke et al., 2020). Thus, the result in Table 3 simply explained that inclusion of animal manure in the diets enhanced the earthworm activities and increased the nutrient composition of the casts summarized in Table 4ab. So, the result findings simply suggested that the use of earthworm especially *Eudrilus eugenae* and castings could be a wonderful tool for waste recycling, nutrient needs for crop production and ecological management.

Table 3. Effect of BA and BUA compost on *Eudrilus eugenae* production

Treatment	Initial wt. of worm gkg^{-1}	Weight of worm at harvest gkg^{-1}	Survival rate of worm	Weight of cast/basket gkg^{-1}	Weight of cast produced/ treatment gkg^{-1}	Size of cast gkg^{-1}
WBA	1.39	8.91±0.65	55.67±0.95	6.76±0.08	35.85	Negligible
WBUA	1.37	10.39±0.58	64.05±1.05	8.35±0.17	45.97	Negligible

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

WBA = Worm work BA compost; WBUA = worm worked BUA compost

Physicochemical and biological properties of *Eudrilus eugenae* cast of WBA and WBUA

The result presented in Table 4ab showed significant difference among the cast of *Eudrilus eugenae* produced from WBA and WBUA on the physicochemical and biological parameters studied. The recorded results showed that the casts were enriched with nutrients, but the recorded value varied with the diet type. Apart from the result of the cast density and dry matter content, the physical parameter values obtained from BA casts (WBA) showed higher values relative to BUA casts (WBUA). While in chemical and biological parameters the BUA casts showed to be richer relative to BA casts except for buffer capacity, soluble mineral cation, C:N ratio, organic N and bacteria counts (4ab). The dry matter and base saturation (BS) value of casts showed a percentage decrease of 5.88% and 2.85% respectively in WBA relative to WBUA, while in WBA aggregate stability and water retention of cast recorded an increase value of 1.23 % and 9.34 % respectively relative to WBUA result. The variation in result of the two vermicasts may be associated to an interaction of physical, and biochemical processes and earthworm activity within the compost type. This interaction processes of which collectively referred to as biogeochemistry defines the ultimate fate of nutrients in a given ecosystem like the compost type. This geochemical reaction might have influenced the oxidation-reduction processes, mineral solubility, nutrient composition and water chemistry of the compost type leading to the nature of result recorded in Table 4ab. According to Ferreras et al. (2006) microbial population differ diet to diet depending on the raw materials of the diet, degree of heat, O_2 present, moisture level, geographical location of the diet and other meaningful considerations. Earthworm relations with some species of plants according to Deleagnola and Nordi, (1987) depends on the chemical composition of the compost materials and show preference to partially decomposed litters. Dozasa-Farkas (1978) noted that they have more preference for animal dejections, while Toutain et al. (1982) attributed the preference to trophic utilization of bacteria, (actinomycetes) and fungi whose cellular constituents undergo rapid lysis after litter ingestion. They ingest dead litter materials with wide C:N ratio (high C) and convert it to narrow C:N ratio (low C) in casts excreted rich in plant nutrients. Earthworm through its activity in humus (vermicompost) production enhance nutrient availability and cycling, aeration, water infiltration and retention and drainage. Humus as reported by Brahmaprakash et al. (2017) is a vital component of soil that affect soil structure, sorption and the organic compounds in soil.

Table 4a. Effect of WBA and WBUA on the physicochemical properties of the *Eudrilus eugenae* cast

Treatment	BD gc m^{-3}	Dry matter %	Water retention	Agg. Stab. %	Silt + clay dispersion	pH H_2O	Buffer Capacity cmol kg^{-1}	Soluble Mineral Cation cmol kg^{-1}	CEC cmol kg^{-1}	Av. P mgk g^{-1}	OC %	N	EC usc m^{-1}	BS %	C:N ratio
WBA Cast	1.238 ±0.17	91.52 ±0.65	11.326 ±0.31	94.45 ±2.78	9.57 ±2.73	6.98 ±0.05	0.89 ±0.07	0.853 ±0.055	25.75 ±0.95	39.51 ±1.49	11.45 ±0.53	0.65 ±0.04	279 ±22	95.75 ±2.97	10:31 ±1.21
WBUA Cast	1.247 ±0.15	96.90 ±0.25	10.265 ±0.286	93.29 ±2.59	7.95 ±1.94	7.05 ±0.15	0.88 ±0.09	0.795 ±0.061	26.80 ±1.70	41.80 ±2.34	13.25 ±0.72	0.56 ±0.035	320 ±25	98.56 ±3.49	9:21 ±1.32

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

Table 4b. Effect of BA and BUA casts on microbial count and population

Treatment	MB $MgCO_3^{-1}$	Bacteria $CFUg^{-1}$	Actinomycetes $CFUg^{-1}$	Fungi $CFUg^{-1}$
WBA cast	21.72±0.41	33.46 x 10^7 ±0.51	45.96 x 10^6 ±1.45	19.65 x 10^5 ±0.36
WBUA cast	26.01±0.34	30.64 x 10^7 ±0.41	51.69 x 10^6 ±1.25	21.25 x 10^5 ±1.02

Second Experiment

Effect of traditional compost (TC) and worm worked compost (WC) on the physical properties of loamy sand soil

The result of the second experiment in which the effect of the five (5) different compost were studied in a loamy sand soil and soybean yield, were summarized in Table 5-9. The result presented in Table 5 showed that for physical parameters statistically significant ($P < 0.05$) difference among the treatments and parameters assessed were recorded in the study in both 2023- and 2024-year studies. Though non statistical result was recorded for BD (2023 year), DR (2023 and 2024 year), temperature (2023 year) and GMD (2024 year) respectively. The physical parameters show vital variations among the treatments considered. The mean value of the parameters assessed indicated that WBA and WBUA that is worm worked compost (WC) to have performed competitively better than the BA and BUA that is traditional compost (TC). This adduced that aggregation, aeration, water transmission, retention and drainage will be more effective in WC (WBA and WBUA) compared to TC (BA and BUA). Zia et al. (2012) noted that soft and friable soil allows air and water to enter easily in the root zone and support large population of beneficial microbes. Evaristo et al. (2015) and Foster et al. (2016) in their own studies observed that plant response to soil moisture conditions and detailed understanding of the soil – root - leaf continuum can be predicted from the hydraulic and water movement in soil. With exception of carbon plants obtain water and nutrients required by their productivity from the soil through the roots (Tinker et al. 2016). Also noticed from the Table 5 is the decrease in value of the parameters as the year of planting increased. This probably may be due to non-application of compost in the 2024 year and increase in soil compaction and total porosity decline. The percentage decrease in TP, WSA, MWD, GMD and DR and temperature in 2024 year relative to 2023-year result in TC were; 16.25%, 23.93%, 6.31%, 34.6%, 1,52% and 9.76 respectively. While it showed a similar result for BD in 2023 and 2024 year and increased MC and Ksat in 2024 year relative to 2023-year result. For WC the decrease in value of 2024 year planting relative to 2023-year results showed 4.76% (BD); 8.24% (TP); 13.11% (Ksat); 15.53% (WSA); 10.48% (MWD); 23.28% (GMD), and 3.81% (DR) respectively. While the 2024-year result showed increased MC, and Temperature relative to the 2023-year result. Temperature is an essential changeable environmental factor that profoundly influence all forms of soil life processes either by increasing or decreasing some of the vital activities of the organisms. It is frequently a limiting factor to growth and distribution of plants and animals. Increase in water use efficiency by compost application through reduction in evaporation might have influenced the temperature result recorded in this study. There is always an inverse relationship between soil temperature and moisture content. The two composts (TC and WC) reduced soil temperature and conserved more moisture relative to the control soil (CO). Above all, the two composts TC and WC (but particularly WC) results in Table 5 showed to be significantly richer than the results obtained from control soil (CO), increased soil physical fertility tested by enhancing the aggregate stability indices measured, decrease in soil BD, increase soil pore volume and soil capacity to hold plant available water. These improvements might be due to increased SOM that binds soil particles together or increased microbial activity and their synthesized products like polysaccharide as this will increase clay hydrophobicity of the soil. A good soil structure in terms of crop production is characterized by optimum BD to support root penetration and development, water and air movement within the soil and optimal water holding capacity and rate of water infiltration (Alley and Vanlauwe, 2009; Diacono and Montemurro, 2010; Mueller et al., 2010; Erhart and Hartl, 2010).

Table 5. Effect of traditional and worm worked compost on the physical properties of loamy sand soil

2023-year										2024 year								
TMT	BD gcm^{-3}	TP %	MC %	Ksat cm hr^{-1}	WSA %	MWD mm	GMD mm	DR %	Temp ^{0}C	BD gcm^{-3}	TP %	MC %	Ksat cmhr^{-1}	WSA %	MWD mm	GMD mm	DR %	Temp 0C
TBA	1.27	51.7	16.56	9.02	21.79	9.95	7.15	0.876	39	1.31	41.50	16.25	8.75	15.25	9.25	4.8	0.876	35
TBUA	1.29	49.7	15.48	10.52	23.04	11.27	8.69	0.962	43	1.24	43.42	18.06	11.01	18.38	10.62	5.56	0.933	39
TC (Mean)	1.28	50.7	16.02	9.77	22.42	10.61	7.92	0.919	41	1.28	42.46	17.16	9.88	16.82	9.94	5.18	0.905	37
WBA	1.25	54.72	18.92	10.58	22.59	13.27	9.21	0.987	41	1.19	48.35	20.15	10.19	19.45	10.82	6.86	0.924	45
WBUA	1.26	57.61	22.52	15.03	24.92	12.68	8.82	0.975	40	1.20	54.72	21.45	12.07	20.69	12.42	6.98	0.965	39
WC (Mean)	1.26	56.17	20.72	12.81	23.76	12.98	9.02	0.981	41	1.20	51.54	20.8	11.13	20.07	11.62	6.92	0.945	42
CO	1.35	39.29	15.30	7.25	18.81	8.59	6.59	0.759	44	1.41	34.32	13.30	6.01	16.09	7.29	4.71	0.735	52
LSD0.05	NS	2.05	1.59	3.17	1.78	2.45	1.88	NS	NS	0.15	3.46	2.65	1.95	2.35	3.07	NS	NS	4.85

TC = traditional compost; WC = worm worked compost; BD = bulk density; TP = total porosity; MC = moisture content; Ksat = hydraulic conductivity; WSA = water stable aggregates; MWD = mean weight diameter; GMD = geometric mean weight diameter; DR = dispersion ratio; Temp = temperature

Effect of the TC and WC on the chemical properties of loamy sand soil

The result presented in Table 6 showed the composts are richer than the control soil. The TC and WC showed statistically similar result in some of the parameters tested. Soil pH reflect the acidity or alkalinity of the soil and controls many chemical processes. This parameter showed slight and moderate acidity in TC 2023- and 2024-year planting respectively. While in WC it varies from alkaline and slightly acidity in 2023- and 2024-year planting. The CO treatment showed strong acidity in both planting years. The implication of the result is that plant nutrient release will vary with the treatment as indicated in Table 6. Some plant nutrient like P is less available in acid soils (and well reflected in Table 6) due to precipitation with Al and Fe ions that are mostly present in low activity clay soils of southeast, Nigeria due to oxyhydroxides of the two ions (Al and Fe). Many authors have found increased soil pH in acidic soils and slightly acidic soils following compost application through base forming cations (Leroy et al., 2007; Erhart and Hart 2010). The implication of the soil pH of 4.8 – 5.6 recorded with CO and to some extent TC particularly of 2024-year planting is that the availability of the base forming cations might be limited because the soil solution chemistry may be mostly occupied by Al^{3+} and H^+ ions. So increased soil pH observed with WC and TC composts can be attributed to increased levels of exchangeable bases. The variation in organic matter content and increased value recorded with WC relative to TC and CO might be attributed to increased hydrolysis of the vegetable polymers by the earthworm (*Eudrilus eugenae*). The relatively small difference observed in OM content of the 2023 and 2024 year, in all the treatments considered might be due to low productivity and reduced decomposition or can be explained in the light of residual effect of the 2023-year planting. Edmundo and Eduardo (2022) opined that soil OM increases the solubility of several nutrients, modifies soil acidity and alkalinity and provides colloids having cation exchange capacity. In addition, organic amendments provide both OC and OM which are closely related in biodiversity, and improve edaphic fertility of the soil, and affect soil properties affecting productive in terms of biomass, contributing element N usually deficient (Laban et al., 2018; Page et al., 2020; Coll 2020). Nitrogen (N) is an important component of chlorophyll and is determined for the high photosynthetic activity, the vigorous vegetation growth and dark green color of the plant. This parameter was found to be statistically similar among the treatments in both 2023^{t} and 2024 year with a decreasing value in 2024-year planting. This might be due to N uptake by soybean or loss through leaching. Organic matter is the main source of N in soil and Table 1 showed that the application of the composts enriched the N content of the soil (Table 6).The increased P content in the treated soils relative to the CO might be attributed to increased organic acid and PO_4 solubilizing bacteria made possible by the application of composts that may have increased the rate of desorption of phosphates leading to the improved availability of P content in the treated soils (Zsolnay et al., 1994; Nweke, 2019). Phosphorous (P) is a component of the complex nucleic acid structure of plants which regulates protein synthesis, thus, important in cell division, development of new tissue and phosphorylation (complex energy transformation). With the exception of the value recorded for control soil (CO), the exchangeable bases (Ca, Mg, K and Na) result obtained from the treated soils are within their critical level (USDA, 1986; Landon, 1991) for crop production, however, the WC is richer relative to the other treatments. Nweke, (2017), and Nweke et al. (2020) noted that soil exchangeable bases (Ca, Mg, K, and Na) generally, increased with the application of cassava peels, fruit and vegetable worm worked composts respectively and that soil base status equally increased when saw dust and straw material compost was applied in Igbariam soil southeast, Nigeria (Nweke and Ijearu, 2018). Meaning that exchangeable bases in treated soils are in readily available forms for soybean uptake. Thus, more superior for the uptake of exchangeable bases relative to the untreated soil. The exchange site was found to be dominated by exchangeable Ca. The decrease in value of exchangeable bases in 2024 year relative to the 2023 year might be associated to soybean uptake, weathering, leaching and probably ferro lysis. The low level recorded from CO indicated low base status and suggests manure application to improve the nutrient base of the soil and this proved the relevance of the study. The CEC and CABC value recorded in the study varied with the treatments and the composts (TC and WC) show superior value compared to value obtained from CO in both years under study. At the same time WC show higher CEC and CABC value compared with TC value. Humic substances are noted to be negatively charged and adsorb more cations protecting them from leaching. This, perhaps increased the value of CEC recorded in the treated soils compared to untreated soil. Generally, soils with large quantities of negatively charged sites are more fertile, because they retain more cations. This probably explain the nature of soybean production result recorded in Table 9ab. The total exchangeable acidity (TEA) recorded in the study was statistically similar in the 2023 year but significantly different among the treatments in the 2nd year planting. The recorded value is low and below the 2.8 – 4.8 cmolkg^{-1}, rated low to moderate value by Brady, (1999). The implication suggests the absence of the possibility of Al^{3+} ion toxicity. Base saturation (BS) result indicated high value (61.39 – 92.31%) and suitable for soybean production (Table 9ab). Wood, (1981) rated BS value of 54 – 74% to be moderately high. The high BS value recorded from the study might be associated with high surface charged content of the SOM provided by the composts applied. In addition, Havlin et al. (2005) noted BS > 65.7% to be high and suggested their dominance in the adsorption complex. The varying composition of the plant species and rate used in the compost production and the influence of *Eudrilus eugenae* on the compost might have contributed to the differentials and statistically significant different recorded among the treatments in both 2023 and 2024year planting. The biomass contributed by the compost with C:N ratio might have enhanced N mineralization by soil microbes in treated soils over the untreated soil. In compost degradation C is oxidized and N is mineralized by microorganisms (Hubbe et al., 2010; Mohee, 2007). Nweke, (2019) found plant residues with low C:N ratio to have enhanced nutrient mineralization particularly N. Generally, the rate of composts applied might have influenced the recorded values in Table 6.

Table 6. Effect of traditional and worm worked compost on the chemical properties of loamy sand soil

2023 year												2024 year							
N %	Pmgkg^{-1}	Ca	Mg	K	Na	CEC	CABC	TEA	BS %	C/N	pHH$_2$0	OM%	N %	Pmgkg^{-1}	Ca	Mg	K	Na	CEC

0.85	8.81	1.98	0.87	0.69	0.58	4.12	1.03	1.61	79.04	9.78	5.69	1.78	0.62	6.59	0.98	0.72	0.52	0.3	**2.52**
0.81	10.79	2.19	1.15	0.82	0.55	4.71	1.18	1.81	69.89	10.99	5.95	2.36	0.7	7.95	0.79	0.68	0.54	0.38	2.39
0.83	9.8	2.09	1.01	0.76	0.57	4.43	1.11	1.71	74.47	10.39	5.82	2.07	0.66	7.27	0.89	0.7	0.53	0.34	2.46
0.98	14.28	2.46	1.63	1.28	0.65	6.02	1.51	1.67	79.94	11.85	6.98	2.26	0.81	9.17	1.56	1.05	0.78	0.38	3.77
0.95	12.59	2.39	1.6	1.19	0.61	5.79	1.45	1.77	79.45	11.06	6.67	2.56	0.68	14.53	1.46	0.99	0.88	0.45	3.78
0.97	13.44	2.43	1.62	1.24	0.62	5.91	1.48	1.72	79.70	1146	6.83	2.41	0.75	11.85	1.51	1.02	0.83	0.42	3.78
0.68	3.89	0.98	0.77	0.59	0.49	2.83	0.71	1.55	62.76	8.61	4.87	0.88	0.58	5.80	0.85	0.68	0.48	0.29	2.30
NS	2.89	0.87	0.43	0.35	NS	1.09		NS	NS	1.25	NS	0.58	NS	2.56	0.49	NS	NS	NS	0.92

CABC = cumulative average of basic cations; CEC = cation exchange capacity; TEA = total exchangeable acidity

Effect of TC and WC on the micronutrient content of soybean, shoot, root and soil

The micronutrients content of soybean shoot, root and soil presented in 7ab showed lower variation among the treatments. The lower variation may be attributed in parts to the rate of compost applied, earthworm activity and the characteristics of *Bacharia* specie and *chromolena odaratum* used for the compost production. All these might have influenced Table 7ab results. The TBA and TBUA (TC) showed similar result for Cu and Pb in soybean root (2023 planting). While WBA and WBUA (WC) had the same value for Pb 0.06 $mgkg^{-1}$(2023 planting) and 0.007 $mgks^{-1}$ (2024 planting) respectively, in soybean shoot and boron (B), 0.006 $mgkg^{-1}$ (2024 planting) in root of soybean. On the average the TBA and TBUA (TC) composts showed higher content in most of the micronutrients in both planting years in the shoot, root (Table 7a) and soil (Table 7b) respectively, compared to their value in WBA and WBUA (WC) composts. Micronutrients are essential elements for food production and quality. Their low concentration in long term diets may cause human malnutrition. Increasing OM content of the soil by compost application can either increase or decrease metal concentration, solubility and availability, plant uptake and recycling. Insoluble organic matter usually forms insoluble organometal complexes, making them less available for plant uptake or leaching. This probably might have explained their lower content observed in shoot and root tissue of soybean. Ahemad and Khan, (2012), Ahemad and Malik (2011) found out many bacteria degrade xenobiotics and sequester heavy metals from root zone. In as much as many organic amendments produce soluble C products through microbial decomposition that can increase metal solubility by forming soluble organometal complexes, lower concentration of the micronutrients in this study can be attributed to less productivity and decomposition of the composts by the soil microorganisms. In biodegradation of OM by microbes in the soil Erhart and Hartl, (2010) noted that micronutrients are released, while Sylvia et al. (2005) argued that the involvement of microbes in biogeochemical cycling of metal depending on microenvironment of the organisms and mechanism involved result in mobilization and immobilization of the metals. Gadd, (2010), however, argued that these cycles are ultimately powered by solar energy fine-tuned and directed by energy expended by the soil microbes. Micronutrients more especially like Mo, B, Zn, Mn, Cu and Fe as explained by Follet et al. (1981) in Theunissen et al. (2010) contribute immensely in the formation of chlorophyll, CHO, cell division, growth and plant enzyme system. Therefore, the type of organic amendments, rate of application and the degradability by microbes and solubility of the decomposable products will have effect on the quantities, and quality of macro and micronutrients with significant effect on the nutrient value of the diet consumed. It has been confirmed through study that organic materials of different type with different quantities of both macro and micro nutrients application in soil has the ability and capacity to supply both macro and micro nutrients in the soil in plant available form for optimal food production and nutrition security. Though the availability and uptake are specific with waste and crop type. Sainz et al. (1998) working with vermicompost found in shoot tissue of red clover and cucumber an increased concentration of Ca, Mg, P, Zn, Mn, and Cu. Oguntade et al. (2017) found increased accumulation of Mn, Fe, Cu, Zn, and Cr in Amaranthus shoot and root as well as soil with an increased application of dye industrial effluent. Working with 4 different rates of wood ash and 3 different tillage methods, Nweke et al. (2017ab) observed that the accumulation of Zn, Fe, Cu, B and Pb in soil, castor shoot and seed does not

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

depend on the rate of wood ash application. On the other hand, the competition between microbes for space, moisture and nutrient and their intimate association with plants in low – nutrient environments like soil studied might have contributed to the micronutrient result obtained from the study.

Table 7a. Effect of traditional and worm worked compost on the micronutrients content of soybean shoot and Root

ent of Soybean Shoot									Micronutrient content of Soybean Root							
			2024 year						2023 year						2024 year	
	Pb	CAHC	Fe	Zn	Cu	B	Pb	CAHC	Fe	Zn	Cu	B	Pb	CAHC	Fe	Zn
35	0.13	0.49	1.09	0.08	0.016	0.082	0.003	0.342	0.31	0.04	0.01	0.015	0.01	0.077	0.056	0.015
05	0.08	0.69	0.96	0.39	0.026	0.37	0.014	0.352	0.26	0.02	0.01	0.013	0.01	0.063	0.042	0.008
7	0.11	0.60	1.03	0.24	0.021	0.226	0.009	0.305	0.29	0.03	0.01	0.014	0.01	0.071	0.049	0.012
45	0.06	0.47	0.36	0.46	0.008	0.007	0.007	0.168	0.14	0.65	0.15	0.05	0.05	0.208	0.023	0.415
7	0.06	0.70	0.67	0.015	0.452	0.105	0.007	0.250	0.16	0.97	0.95	0.013	0.08	0.435	0.046	0.365
58	0.06	0.58	0.52	0.24	0.23	0.056	0.007	0.211	0.15	0.81	0.55	0.032	0.07	0.322	0.035	0.39
25	0.36	0.35	0.48	0.00	0.012	0.035	0.096	0.125	0.11	0.04	0.05	0.01	0.05	0.052	0.017	0.009
36	NS		0.45	NS	NS	NS	NS		NS	0.29	0.65	0.008	NS		NS	0.33

CAHC = cumulative average of heavy metal ion concentration

Table 7b. Effect of traditional and worm worked compost on the micronutrients content of soil

TMT	Micronutrient content of Soil									
	2023 year					2024 year				
	Fe	Zn	Cu	B	Pb	Fe	Zn	Cu	B	Pb
TBA	25.5	10.35	9.21	25.68	3.07	9.589	4.63	5.63	0.938	2.02
TBUA	25.57	11.09	10.18	18.15	3.16	7.571	6.56	4.23	2.251	1.96
TC (Mean)	25.54	10.72	9.7	21.92	3.15	8.58	5.6	4.93	1.595	1.99
WBA	13.6	10.38	12.76	16.75	4.25	5.176	5.61	3.08	0.882	2.51
WBUA	19.31	10.43	11.25	11.85	4.76	3.15	3.43	5.17	1.102	2.06
WC (Mean)	16.46	10.41	12.01	14.32	4.51	4.163	4.52	4.13	0.992	2.29
CO	7.11	8.2	8.06	12.04	2.31	3.38	3.28	4.23	0.296	1.36

LSD0.05	4.67	1.85	2.08	3.15	NS	2.15	NS	NS	1.28	NS

Effect of TC and WC on biological properties of loamy sand soil

The result of soil biological properties in Table 8 showed statistical ($P < 0.05$) significant difference among the treatments except for WSC and MBC (2023 year), MBC (2024 year) and fungi count in 2024-year planting. The application of composts was observed to have increased the WSC and MBN in relation to the initials (Table 1), though the increase, decreased relatively in the 2024-year planting. The value recorded for WSC, MBC and MBN varied among the treatments in both years understudy, but where found to be higher in WBA and WBUA (WC) relative to TBA and TBUA (TC) and untreated soil (CO). The rate of composts applied and differentials in the amount of OM contributions by the treatments, solubility, due to varietal difference in materials used for the compost might be responsible for the difference in WSC, MBC and MBN results among the treatments studied in both years understudy. Under Sudan Savanna soil of Nigeria, Mohammed et al. (2017) found increased MBC, WSC and MBN in all nitrogen fertilized treated plots relative to the initials and untreated plots. Soil is an important habitat for many microorganisms according to Akhar et al. (2013), they are habitats between soil particles and SOM in rhizosphere where they mediated about 80 – 90% reaction processes. Among the most labile N and C pools in soil are MBN and MBC of which are indicators of sustainable management system and determined by the population and activity of the soil microbes and other biological ecosystems. Hence their influence on the plant nutrient availability, sequestration of heavy metals and detoxification in agroecosystem. Thus, the potential use of amendment like the composts studied that can improve soil resilience and beneficial in soil nutrient restoration and productivity becomes ideal in nutrient deficient soil like loamy sand soil. Soil microbiological communities determine changes in soil chemistry, and critical factor in plant nutrient availability in soil and provide nutrient from soil to the plants (McDaniel et al., 2014; Sun et al., 2020; Yang et al., 2020; Tederso et al., 2020). In pepper culture in soil amended with biochar and compost, Sulok et al. (2021) recorded positive effect on abundance of bacteria, actinomycetes and fungi, bulk density, porosity, OC and available P and high yields similar to those obtained with mineral NPK. Unagwu, (2019) worked on degraded sandy loam soil using four (4) different organic amendment and found increased microbial biomass C, OC, available P and exchangeable K compared to the unamended soil. Ready Hough et a. (2021) worked on tomato cultivation using different manure amendment, they concluded that the amendments affect the microbial community of bacteria and fungi but particularly fungi and improved the soil porosity, and water holding capacity.

The microbial biomass and counts differed among the treatments and increased relative to the untreated soil and initials MB (Table 1). Compost of organic wastes stimulate microorganism's activity in soils, accelerate OM mineralization, hence support the activation and growth of microbes in soils (Scotti et al., 2016; Hermandez et al., 2018). However, results were found to have decreased in 2024-year planting probably due to less amount of OM due to non-application of composts or residual effect of 2023 year planting. Fungi counts were found to be less in both years of study compared to bacteria and actinomycetes. This might be attributed in part to the type of organic material and its mineral and metal content, temperature, water content and pH levels of the treatments. Bacteria, actinomycetes and fungi as observed by Mohee (2007) prefer different types of organic material and they become dormant or die when these specific OM materials required for their growth and production are no longer available. Availability of water affect the diffusion of water and soluble nutrients into and out of microbial cells. Also, microorganism interact with nutrients and metals in organic material altering their physicochemical state while metals and minerals affect their activity, growth and survival. Again, temperature and pH levels of the productive activity varies with microorganism, Hubbe et al. (2010) found microbial activity to be optimal at pH range 6.5 – 8 but bacteria prefer pH range 6.0 – 7.5 whereas fungi prefer pH range 5.5 – 8.9 for optimal activity. This observation is in line with the result of the present study (Table 6). Soil microorganisms play vital role in OM degradation leading to humus formation and nutrient availability. They play significant role in plant nutrient release and nutrition, soil dynamics, quality and quantity of SOM content and agricultural products (Welbaum et al., 2004; Brimecombe et al., 2007; Collignon et al., 2011; Barea et al., 2013; Lugtenberg 2015; Brahmaprakash et al., 2017). Mapelli et al. (2012) observed that they contribute efficiently to plant growth and yield in nutrient poor soils. This report is in line with the soybean production result recorded in Table 9ab. The stability of soil OM and its quality and quantity according to Bhattacharya et al. (2022) is controlled by the viability of soil microbial community.

Bhattacharya et al. (2000) also found increase bacteria, actinomycetes and fungi counts in worm worked composts compared to traditional compost. In long term study of biofertilizer and mineral fertilizer on biological activity, Brown and Cotton (2011) observed enhanced microbial activity and higher biomass in bio-fertilized treated field plots. Increased microbial biomass and counts observed in WC relative to TC and untreated soils might be associated to the fact that reports by Haritha Devi et al. (2009), Parthasarathy and Ranganathan, (1998) showed considerable increase in the total bacteria and actinomycetes viable counts in worm treated compost.

Table 8. Effect of traditional and worm worked compost on the soil biological properties of loamy sand soil

TMT	2023 year			2024 year			2023 year				2024 year			
	WSC %	MBC Mgkg^{-1}	MBN Mgkg^{-1}	WSC %	MBC mgkg^{-1}	MBN mgkg^{-1}	MB MgCO$_3^{-1}$	Bact. g^{-1}	Fungi g^{-1}	Act. g^{-1}	MB MgCO$_3^{-1}$	Bact. g^{-1}	Fungi g^{-1}	Act. g^{-1}
TBA	3.76	66.93	5.26	1.8	53.96	3.29	16.28	6.08	3.2	5.12	11.46	3.9	1.46	0.75
TBUA	4.96	69.34	5.43	3.05	56.35	3.85	15.68	5.98	3.5	4.19	11.26	4.2	1.52	1.07
TC (Mean)	4.36	68.135	5.35	2.43	55.16	3.57	15.98	6.03	3.35	4.66	11.36	4.05	1.49	0.91
WBA	5.86	68.49	6.35	2.93	57.79	4.27	22.55	9.72	4.68	6.42	18.78	4.47	2.76	2.16
WBUA	4.58	70.27	5.84	3.54	54.78	3.68	25.61	8.64	5.38	5.89	19.22	4.59	2.89	1.89
WC (Mean)	5.22	69.38	6.1	3.25	56.29	3.98	24.08	9.18	5.04	6.16	19	4.53	2.83	2.03
CO	3.09	55.25	2.73	1.25	41.13	2.03	10.07	3.85	0.95	0.54	10.58	2.47	1.35	0.98
LSD0.05	NS	NS	0.87	0.95	NS	1.07	5.04	2.53	2.09	1.78	3.74	0.69	NS	0.56

WSC = water soluble carbon; MBC = microbial biomass carbon; MBN = microbial biomass nitrogen; MB = microbial biomass.

Effect of TC and WC on soybean production in a loamy sand soil

The greatest influence of bio-fertilizer is its efficiency in recharging soil fertility, promotion of soil biology that enhance the solubility and bioavailability of most soil nutrients for uptake and use by the plant. Thereby contributing to soil nutrient pool and in the management of degraded and marginal soils. In long term agricultural activities, they can partly substitute agrochemicals (very expensive and dangerous to soil and crops) if properly and adequately employed for sustainable food production. Especially were plant nutrients are substantially reduced with cropping in humid zone of southeast, Nigeria following heavy rain fall, high temperature and the fragile nature of the soil. Legume crops are noted for their symbiotic N fixation with rhizobium, ease of pressure on yield from other crop, thus diversifying the agricultural production system.

Over the years through study (Nweke, 2016; Nweke et al., 2022; Nweke and Anene, 2019; Nweke and Emeh, 2013) legume production have been found to decline greatly following physicochemical properties of the soil where it is planted, choice of manure and wrong application and to lesser extent pest and diseases. Manure application is an important process in crop production service and have being noted by Abu et al. (2008) to greatly influenced the physiological processes of crop needs especially with regards to plant nutrients. In the present study soybean production in southeast, Nigeria was studied for 2 years. The results obtained recorded in Table 9ab showed statistically significant different ($P < 0.05$) among the treatments except for the fresh root density and root to shoot ratio for the years understudy. Also, reduction in value was observed as the planting year increased probably as a result of non-application of the compost in the 2024year and residual effect on the 2023-year planting. The average plant height, leaf area, number of nodules and weight of nodules in both 2023[t] and 2024 planting increased in all the amended soils relative to the control. The highest recorded value for each of the parameter in both years of study showed that the tallest plant of 60.58cm (2024 year) and 57.75cm (2024year) were obtained from WBA. The order of height increases in both years is WBA > WBUA > TBA > TBUA > CO. Dry matter yield of soybean was observed to be better in all the treated soils relative to the control soil. The highest recorded value of 46.25 gkg^{-1} and 31.39 gkg^{-1} for shoot dry matter yield 2023 and 2024 year was obtained from WBUA and WBA respectively. While root dry matter yield showed highest in WBA (14.65 gkg^{-1} and 9.78 gkg^{-1}) respectively for 2023- year and 2024-year planting. The recorded decrease in value in the 2024-year planting among other things may have resulted from insufficient soil nutrients. Adequate plant growth and development is very important for yield improvements and final dry matter yields. To achieve this in nutrient deficient soil like loamy sand soil sufficient amount of nutrients need to be applied through organic sources like composts studied. And the study has shown that the composts studied contains a higher amount of nutrient necessary for soybean growth in readily available forms which led to improved growth and dry matter yield observed. Yield improvements may be associated to a well aggregated soil (Table 5) impacted by the composts. Thus, creating an O_2 rich environment that may have favored many beneficial microorganisms important in N fixing, PO_4 solubilization, and K. As well as a host of other soil reactions that assist in soil nutrients mineralization. The low value recorded in control soil may be attributed to phosphorous deficiency in the soil. In mineral nutrition study, Nichols (1965) observed that omission of P significantly decreased nodule count in pigeon pea relative to other elements. Increased plant height, number of flowers and branches, leaf area, nodule counts, root length, and pod weight in Bambara ground nut (Nweke and Emeh 2013) and nodule count in soybean Glycine max (Qiao et al., 2007) with increased P sorption further illustrated the importance of phosphorous in legume growth, nodule formation and yield. Though further study like tissue nutrient analysis, are required to confirm that soybean plant in this study were not phosphorous deficient. As shown in Table 9ab WBUA (223.81 % 2023year) and WBA (202.72% 2024year) respectively gave the highest soybean yield increase over the control in both the 2023 and 2024 plantings. While the lowest were obtained with TBA treatment. Among the treatments studied, WBUA gave the highest yield reduction followed by TBUA and the least of 27.27% obtained from TBA. This could be attributed to fast decomposition of WBUA and TBUA suggesting that most of their nutrients were released during the first growing season of the soybean. The fast decomposition may be associated to the C:N ratio of the amendments. TBA showed the lowest yield reduction and high residual effect, indicating that the decay and release of nutrients were slowly in this compost. Generally, the amendment that produce the highest dry matter yield during the 2023 planting season gave the worst residual effect. But in this study the residual effect of the composts studied were not relatively bad meaning that they can adequately support crop growth and yield for 2 years without further application of compost. Residual effect of different soil amendments on crop establishment, growth and yields are documented in Nweke, (2018) and Nweke et al. (2022). The root length and density, and root to shoot ratio often used to characterize the crop root distribution systems and its influence on water extraction pattern on soil layer, changes in rain fall pattern and irrigation differed among the treatments. This might be due to the quantity of released organic chemicals (exudates) from soybean roots of which are influenced by micro soil factors and water content of the treatments. Root exudates provide the driving force for the development of active microbial population at the root zone, motivating root growth, development and enrichment of the surrounding soil through nutrient mineralization. The statistical none significant ($P < 0.05$) recorded by the parameters may be associated to water content of the treatments, root proliferation nature and demand for water and enclosed (greenhouse) experiment. Besharat et al. (2010) in their study of parametric modelling of root length and root water uptake of apple tree in unsaturated soil observed that root activity with regards to changes in soil water was concentrated in the surface soil layer.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

They also reveal that deep and younger roots part of the root systems did not extract water as efficiently as shallow/older roots. This they suggested according to Pierret et al. (2006), that a significant axial resistance could exist in deeper roots. Root distribution and hydraulic properties and soil characteristics requires precise integrated study for crop root water uptake requirements.

Table 9a. Effect of traditional and worm worked compost on soybean production on a loamy sand soil (Year 1)

TMT	2023 year									
	PH cm	LA cm^2	ND	WD gkg^{-1}	RL cm	FRD gcm^{-3}	RT:SH (F)	SHD gkg^{-1}	RDM gkg^{-1}	TDM gkg^{-1}	YIO %
TBA	56.45	26.99	223	5.84	22.75	1.43×10^{-3}	0.661	39.63	10.58	50.21	160.85
TBUA	54.11	28.62	206	3.97	26.06	1.42×10^{-3}	0.674	40.49	13.94	54.43	192.63
TC (Mean)	55.28	27.81	214	4.91	24.41	1.43×10^{-3}	0.668	40.06	12.26	52.32	176.74
WBA	60.58	30.75	344	3.55	24.85	1.46×10^{-3}	0.645	44.17	14.65	58.82	216.24
WBUA	59.87	30.82	442	3.94	26.96	1.54×10^{-3}	0.707	46.25	13.98	60.23	223.82
WC(Mean)	60.23	30.79	393	3.75	25.91	1.5×10^{-3}	0.676	45.21	14.32	59.53	220.03
CO	41.35	9.78	27.51	0.27	18.87	1.36×10^{-3}	0.504	18.72	0.48	19.20	
LSD0.05	11.58	8.45	15.85	1.09	2.39	NS	NS	6.53	10.04		

PH = plant height; LA = leaf area; ND = number of nodules; WD = weight of nodule; RL= root length; FRD= fresh root weight density; RT : SH (F) = fresh root to fresh shoot ratio; SHD = shoot dry matter; RDM = root dry matter; TDM = total dry matter; YIO = yield increase over control

Table 9b. Effect of traditional and worm worked compost on soybean production on a loamy sand soil (Year2)

TMT	2024 year											
	PH cm	LA cm^2	ND	WD gkg^{-1}	RL cm	FRD gcm^{-3}	RT: SH (F)	SHD gkg^{-1}	RDM gkg^{-1}	TDM gkg^{-1}	YIO %	YR %	RES %
TBA	47.93	24.7	143	4.78	11.75	0.25×10^{-3}	0.214	28.56	7.97	36.53	160.53	27.27	72.75
TBUA	48.83	23.98	164	3.48	16.09	0.444×10^{-3}	0.253	28.61	8.18	36.79	170.51	32.52	67.49

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

TC (Mean)	48.38	24.34	153.5	4.13	13.92	0.348×10^{-3}	0.234	28.59	8.08	36.66	165.52	29.9	70.12
WBA	57.75	29.98	223	2.94	20.75	0.293×10^{-3}	0.212	31.39	9.78	41.17	202.72	29.99	69.99
WBUA	57.33	28.72	206	3.84	21.69	0.244×10^{-3}	0.272	30.89	8.61	39.5	190.44	34.45	65.58
WC (Mean)	57.49	29.35	214.5	3.39	21.22	0.269×10^{-3}	0.242	31.14	9.20	40.34	196.58	32.22	67.79
CO	39.63	8.76	11.14	0.11	9.85	0.233×10^{-3}	0.201	13.53	0.065	13.6		29.27	70.73
LSD0.05	8.06	11.85	15.98	2.19	3.15	NS	NS	2.75	5.05			0.98	0.65

PH = plant height; LA = leaf area; ND = number of nodules; WD = weight of nodule; RL = root length; FRD = fresh root weight density; SHD=shoot dry matter; RDM = root dry matter; TDM = total dry matter; YIO = yield increase over control; YR = yield reduction; RES = residual effect

CONCLUSION

In agricultural activity, crop production is mainly controlled by the provision of essential macro and micro nutrients and other essential growth promoting substances. The decomposition results showed that BUA decomposed faster and released its nutrients quickly and influenced the activities of *Eudrilus eugenae* earthworm more than the BA compost. The cast production analysis of the worm worked composts (WBA and WBUA) showed that earthworm activity enriched the two composts with minimal variations in the recorded value of the parameters tested. The results of the study proved that the four composts studied contains these essential nutrients in readily available form because in soybean culture amended with different types of composts recorded positive effect on soil physical, chemical and biological properties, abundance of bacteria, actinomycetes and fungi and high yield of soybean. Soil amendments such as composts studied are biological practices that has good promise for improved soil productivity and reduce soil erosion. The results revealed that the composts studied have a high fertilizing value with good potential for restoration of productivity of degraded loamy sand soil. Due to enhancement levels of macro and micro nutrients, biological and soil pH, the composts were able to improve the fertilizing status of the soil. The study proved that compost applications no matter the type are potential pollutants as soybean root and shoot are enriched with heavy metals though not above their critical limit. Above critical limit is detrimental and hazardous to humans, animals and even soil as it may lead to soil degradation. In characterization of the nutrients and agronomic ranking of the composts, the worm worked compost (WBUA) fared better as it improve soil quality, enhance soybean growth and yield compared to other composts especially in the 1st year planting, though not in all the parameters studied. In 2nd year planting the ranking of the soybean yield increase over the control and residual effect respectively were; WBA > WBUA > TBUA > TBA and WBUA < TBUA < WBA < TBA < CO. With increase in awareness of organic food production, organic waste material processed traditionally or more especially by natural occurring organism *Eudrilus eugenae* earthworm can be used to produce compost which will provide the nutrients for crop growth, enhance yield and improve soil quality. Using this study as a guide, it is worthy while, that organic farmers/gardeners establish an ideal rate of application of compost in order to achieve this objective. It is however, recommended that this study be carried out in the field to confirm the results and conclusions from this greenhouse study.

ACKNOWLEDGEMENT

The authors are grateful to Mrs. Roseline Chukwuma and her team, at Soil Science laboratory, Nnamdi Azikiwe University, Awka, and cordial relationship that exited while doing the analysis for us and by withstanding the pressure mounted on us by our supervisors and given the results of the analysis to us even with our meager resources. May God favor her and her team.

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