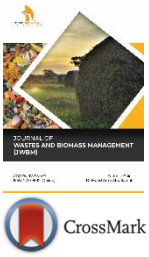
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2710-6012 (Online)
CODEN: JWBMAO

Journal of Wastes and Biomass Management (JWBM)

DOI: http://doi.org/10.26480/jwbm.02.2022.73.77



RESEARCH ARTICLE

COMPARATIVE EFFECTS OF MINERAL FERTILIZER, COMPOST AND COMPOST – MINERAL FERTILIZER ON BIOLOGICAL, CHEMICAL AND PHYSICAL PROPERTIES OF SOIL

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ARTICLE DETAILS

Article History:

Received 21 May 2022
Accepted 27 June 2022
Available online 04 July 2022

ABSTRACT

The rapid decline of organic matter in the tropics makes it necessary to incorporate compost or compost – mineral fertilizer into the soil to improve the soil organic matter content and fertility. The experiment to investigate the effects of mineral and organic base fertilizer on soil organic matter, nutrient content, aggregate stability and the fungi isolates was conducted in Ambrose Alli University, Ekpoma, Nigeria. Experimental design was a Randomized Complete Block Design with five treatments replicated thrice. The treatments were; control, Urea, NPK 15 15 15, Compost and Compost – mineral fertilizer. Compost and compost – mineral fertilizer rates was 10 and 4 tonnes / hectares (t ha^{-1}) respectively. Maize was used as test crop. The soil at the experimental site was low in nutrients however, the application of compost and compost – mineral fertilizer significantly ($p \leq 0.05$) improved the organic matter content, soil nutrient status and aggregate stability compared to mineral fertilizer. The fungi isolates was higher in compost and compost – mineral fertilizer. The application of compost and compost – mineral fertilizer increased the soil pH to near neutral and reduces acidity. The application of compost – mineral fertilizer had multiple benefits in improving organic matter content, the chemical and physical and biological properties of the soil. In conclusion, compost – mineral fertilizer had significant improvement on the soil nutrients and aggregate stability compared to other treatments, therefore compost – mineral fertilizer can be effective in the sustainability of the soil fertility.

KEYWORDS

Aggregate stability, acidity, compost, compost – mineral fertilizer, mineral fertilizer, fungi.

1. INTRODUCTION

Soil is a natural resource which supports life, Agriculture generally depend on soil however, the maintenance of this essential resource is mostly neglected as human induced the cause of soil degradation. The rapid decline in soil organic matter, nutrients and the inherent low fertility of tropical soil called for immediate attention. Moreover, the challenge of adequate food production in Africa due the annual increase in population growth of 3% is alarming furthermore over half of the African population is rural area are directly dependent on crop production (Bationo et al., 1998). Crop production largely depend on the fertility of the soil, which has been faced with problem of degradation. Land degradation is the decline in quality of the soil, biological, chemical and physical properties of the soil which resulted from human induced factors. And it will continue to be an important global issue due to its adverse effects on Agriculture (Eswaran et al., 2001).

It become necessary to sort for methods to combats the rapid decline of organic matter and soil nutrient. The management of soil through the application of fertilizer is very essential. The application of fertilizer; inorganic or organic and both is a means to amend the soil for higher productivity. Despite the advantages derived from the use of chemical fertilizer in increasing soil fertility and crop production, however, there are some limitations which make these fertilizers unsuitable; as it adversely affects micro-organism, increase soil acidity and degrade natural fertility of the soil, due to decline in organic matter. Improvement of soil organic matter can be derived from the application of animal manure, compost, plant residues as well as organic base fertilizer.

Organic base fertilizer which includes compost, animal manure, plant residues and compost – mineral fertilizer improves soil health and environmental quality, also reduce environmental pollution (Hati et al., 2007). The integrated use of composted manure and chemical fertilizers has emerged as a promising option, as it enhances better nutrient release and satisfies crop requirement during the growth and development stage (Busari et al., 2008). Compost – mineral fertilizer improves the organic matter content and reduces acidity of soil as well as significantly ($p \leq 0.05$) increased the yield of crops (Dania et al., 2021). It is therefore, the objective of this study to evaluate the comparative effects of compost, compost – mineral and mineral fertilizer on soil properties.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

The experiment was conducted at the Teaching and Research Farm, Faculty of Agriculture, Ambrose Alli University, Ujemen campus, the location is in the humid rainforest vegetation belt of Nigeria, lying between latitude $6^{0}42'$ North and longitude $6^{0}8'$ East, with a mean annual rainfall of 1500mm and temperature $15^{0}C$ - $34^{0}C$.

Quick Response Code	Access this article online	
	Website: www.jwbm.com.my	DOI: 10.26480/jwbm.02.2022.73.77

Cite the Article: Dania Stephen Okhumata, Dania Margaret Iyabode (2022). Comparative Effects of Mineral Fertilizer, Compost and Compost – Mineral Fertilizer on Biological, Chemical and Physical Properties of Soil. *Journal of Wastes and Biomass Management, 4(2): 73-77.*

2.2 Sample Collection and Analyses

Composite soil samples (0-15cm) were collected from the experimental plots prior to planting and after harvest to ascertain the nutrient status of the soil. The soil samples were air dried, sieved and analyzed for biological, physical and chemical properties. Particle size distribution was determined by hydrometer method (Bouyoucos, 1962). The pH was measured in a 1:1(soil-water) by glass electrode pH meter, organic carbon was determined by the wet dichromate acid oxidation method (Maclean, 1982; Nelson and Sommers, 1982). Total nitrogen was determined by the micro kjedahl method, available phosphorus was determined by Bray-1 extraction method (Bremner and Mulvaney, 1982; Bray and Kurtz, 1945). Calcium (ca), magnesium (mg), sodium (Na) and potassium (K) were extracted with NH_4OAC pH 7.0 (Ammonium acetate). Potassium and sodium were determined with flame emission photometer while calcium (Ca) and magnesium (Mg) were determined by the atomic absorption spectrophotometer (IITA, 1979). ECEC was calculated by the summation of exchangeable base and exchangeable acid (Anderson and Ingram, 1993).

2.3 Experimental Design

The experimental design was Randomized Complete Block Design (RCBD) with five treatments replicated three times. The treatments were: control (zero application), compost (10 t ha^{-1}), compost – mineral fertilizer (4 t ha^{-1}), NPK (15 15 15) (300 kg ha^{-1}) and Urea (265 kg ha^{-1}).

2.4 Statistical Analysis

All data collected were analyzed statistically using the Analysis of variance (ANOVA) test and the least significant difference (LSD) was used to separate means that significantly differs at 5% probability (SAS, 2005).

2.5 Cultivation, Planting and Management Practices

The pre-planting operations carried out includes site selection, clearing of vegetation, packing of debris, mapping, and herbicide application. The planting area measured 15m x 9m, the trial was laid in 15 plots; each plot size (consisting of flatbeds) measured 2m x 2m. The maize variety used for planting was SUWAN-1-SR with three (2) seeds sown per hole at a spacing distance (standard spacing) of 75cm x 25cm and later thinned to one plant.

2.6 Composting and Fertilizer Application

The various organic materials such as pig dung, poultry manure, sawdust, and rice bran were composted for twelve weeks. After curing, the compost was air dried and fortified with NPK (ratio 8:1. Composition: 40 kg by volume of compost and 5 kg of NPK to make up 45kg). Compost application rate at 10 t ha^{-1}, compost- mineral fertilizer at 4 t ha^{-1}, NPK application rate at 300 kg ha^{-1} and urea at 265 kg ha^{-1} and control (zero application). The fertilizers were applied two weeks after planting.

2.7 Isolation of Fungi

One gram from each of the soil samples was used for serial dilution using 9% Sodium chloride as diluents up to 10^6. Pour plate technique of Robert and Greenwood (2003) was used. Measured 1ml of 10^3 and 10^5 dilutions were aseptically introduced into sterile petri dishes in duplicates. Sterilized Potato dextrose agar (PDA) was used for the fungi isolation. Chloramphenicol (250mg/L) was added to the cooled sterilized Potato Dextrose Agar (PDA) to inhibit bacterial growth. Inoculated Petri-dishes were left at room temperature for 4 days to allow the growth of fungi.

2.8 Identification of Fungi

The fungal isolates were identified based on their cultural and morphological characteristics. The microscopic examination of the isolates was carried out using wet staining with lactophenol cotton blue and observation was carried out using X40 objective (Gaddeyya et al., 2012).

2.9 Percentage Aggregate Stability (%AS)

Percentage aggregate stability (%AS) was carried out using the wet sieving method (Kemper, 1965). Sieved air-dry soil samples weighing 200g from each replicate were placed in nest of sieve and immersed in a bowl of water. The sieves were oscillated vertically and rhythmically so that water was made to flow up and down through the screens and the assemblage of aggregated. In this manner the action of flowing water was simulated. At the end of the specific period of sieving (30 minutes), the nest of sieves containing the let over soil was removed from the water, oven dried and weighed. The results were corrected for the coarse primary particles retained on each sieve to avoid designating falsely as aggregates. This was done by dispersing the materials collected from sieve, using a mechanical stirrer and a sodic dispersing agent (calgon) then washed through the same sieve. The weight of sand retained after second sieving was subtracted from the total weight of the undispersed material retained after the first sieving.

Percentage of Stable Aggregate (%SA) was estimated as follows:

% SA= (Wt. retained) – (Wt of Sand) / (Total sample wt) - (Wt. of Sand) x 100.

3. Results and Discussion

According to application of organic amendment enhanced the of the soil biologically, chemically, and physically (Atere and Olayinka, 2012). The nutrient content of the soil at the experimental site was low below critical level. The soil pH was slightly acidic, compost and compost – mineral fertilizer had pH value of 8.13 and 8.18 respectively (Table 1). The soil pH to 6.92 was increased and 6.34 in plot with the application of compost – mineral and compost respectively (Table 2). Organic base fertilizer had a slight alkaline pH which favors the activities of soil organisms and positively affects availability of nutrients in the soil. Compost application has a liming effect on soil due to its richness in alkaline cations such as Ca, Mg and K, which are release from the organic matter during mineralization, compost therefore can be used as liming material (Worku, 2021).

Table 1: Physical and chemical properties of the soil and compost – mineral fertilizer

Parameter	Soil	Compost -Mineral	Compost Fertilizer
P^H (1:1) H^2O	5.68	8.18	8.13
OC (g/kg)	14.56	47.18	37.23
N (g/kg)	1.43	4.16	2.01
P (mg/kg)	9.55	38.37	25.35
Exchangeable Bases (cmol/kg)			
Ca^{2+} ,,	4.32	5.45	5.33
Mg^{2+} ,,	1.83	13.35	6.37
K+ ,,	0.10	19.62	8.14
Na+ ,,	0.28	6.42	4.67
Exchangeable Acidity (cmol/kg)	0.24	9.20	4.00
ECEC ,,	6.53	44.84	24.51
Mn+mg / kg	57.56	98.80	20.24
Fe^{2+}	6.21	15.60	12.24
Cu^{2+}	2.16	11.10	8.46
Zn+	0.74	23.30	15.66
Particle Size Distribution (g/kg)			
Sand	932.00		
Silt	18.00		
Clay	50.00		
Textural class	Sandy Loam		

The application of NPK and urea had no influence on the soil pH, urea slightly reduces the pH. The decomposition of organic matter increased microbial activities as the organism derived their carbon source and resulted in the release of more exchangeable bases such as K, Ca, and Mg that reduce the soil acidity near to neutrality and the results was in agreement with the study carried out (Lee et al., 2009). They reported that the application of organic materials such as crop residues, green manure, and compost improved soil pH, available nutrients, organic matter content, and reduced exchangeable acidity. The results of the initial soil organic carbon content values of the experimental location was 14.56 g kg^{-1} were below the critical level of 15g/kg (Enwenzor et al., 1989). The application of compost and compost mineral fertilizer improved the residues of the organic carbon content in the soil when compared to other fertilizers applied (Table 2).

Treatments	pH (H^2O)	O.C	T.N	Av. P	Ca	Mg	K	Na	Ex. Acidity	ECEC	Mn	Fe	Cu	Zn	Sand	Clay	Silt
		g/kg	g/kg	mg/kg	← Cmol/kg →						→ mg/kg →				← g/kg →		
Control	5.64	10.18	0.74	9.71	2.12	0.36	0.25	0.03	0.60	2.76	68.50	6.10	0.01	0.62	894	40	66
Urea	5.64	9.60	1.64	10.15	3.52	1.13	0.19	0.37	0.60	5.21	78.10	6.40	0.04	12.25	864	60	76
NPK	5.74	10.81	1.90	18.84	3.64	2.09	0.41	0.59	0.80	6.73	91.90	7.50	0.02	11.16	854	70	76
Compost – mineral	6.92	27.40	3.66	25.35	12.95	2.52	0.49	1.39	0.80	17.35	95.50	11.40	0.26	13.74	876	54	20
Compost	6.34	19.58	1.69	20.01	10.26	2.62	0.40	0.68	0.16	13.96	88.82	17.02	0.18	8.04	892 Texrural	54 class	14 Sandy loam

Table 2: The residual effects of different fertilizer on the chemical and physical properties of the soil plante with maize at the AAU, Emaudo campus site

The organic carbon (organic matter) content in organic base fertilizer (compost and compost – mineral fertilizer) consequently improved soil fertility. Soil organic matter has large surface areas, exchange sites, retain cations in exchangeable forms, it increases availability of Zn also it strongly held some micronutrients such as Cu and Mn. It is important to note that organic matter enhances the formation of chelates and other soluble organic complexes, these characteristics make organic matter very important in the soil (Masmoudi et al., 2020). Mineral fertilizer, NPK and urea had no significant effects on the organic matter content of the soil but rather reduces it (Table 2).

The nitrogen and phosphorus content of the soil was below critical level and application of fertilizer increased the nitrogen and phosphorus content, however, compost base fertilizer had higher residual effects on the soil. And according to the application of organic base fertilizer significantly ($p \leq 0.05$) increased the nitrogen and phosphorus content compared to the application of mineral fertilizer alone and the finding was in agreement with the results obtained from this experiment (Tanwar et al., 2016). The residual content of total nitrogen and available phosphorus were significantly ($p \leq 0.05$) higher from the application of compost and compost – mineral fertilizer compared to the applications of mineral fertilizer and control. Application of organic amendments to soil enhances soil N, P and K concentrations especially when applied with inorganic fertilizer (Hao et al., 2003).

The application of compost and compost – mineral fertilizer improved the cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) content and these positively affects the ECEC of the soil. The content of Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} in compost and compost-mineral fertilizer were higher above the critical levels (Masmoudi et al., 2020). The application of fertilizer increased Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} than the control. It is ascertained that the appropriate application of fertilizer increased the cations above critical level as established (Amalu, 1991). From the experiment, the application of fertilizer increased the values of exchangeable cations however, organic base fertilizer had significant ($p \leq 0.05$) higher exchangeable cations compared to sole application of mineral fertilizer (Table 2). According to the combined application of farmyard manure and mineral fertilizer significantly ($p \leq 0.05$) increased the exchangeable cations content with higher residual in the soils (Agegnehu, 2014; Brown and Cotton, 2011).

Also, soils with a low CEC are more likely to develop deficiencies in potassium (K^{+}), magnesium (Mg^{2+}) and other cations while high CEC soils are less susceptible to leaching of these cations, hence, the application of fertilizer to soil improved its CEC. The ECEC of the soils were below the critical level of 15 cmol/kg with the application of mineral fertilizer and compost but higher above the critical level with the application of compost – mineral fertilizer as reported (Udo et al., 2009). The application of compost to soils can result in a significant increase in concentrations of N, P, K, Ca, Mg and S as well as a variety of essential trace elements in soil (Butler et al., 2008). The manganese, iron and Zinc content of the soils were above the critical value of 5 mg/kg while the copper values were below the critical value of 2 – 3 mg/kg (Amhakhian and Osemwota, 2012).

3.1 Aggregate Stability

Aggregate stability is a crucial soil property that affects soil sustainability and crop production. The incorporation of organic matter informs of manure or compost increase soil aggregate stability (Tejada et al., 2009). The cereals crop influence soil aggregation through the root structure and distribution, quality and quantity of carbon inputs, effects on soil microclimate and microbial communities and their activities (Worku, 2021). Organic matter content of the soil and the presence of soil biota significantly increased soil aggregate stability (Debosz et al., 2002). Macro aggregates are stabilized by fungal hyphen, fine roots, root hair and microorganisms with addition of compost in the soil (Amlinger et al., 2007). Fertilizer applications have the potential of altering soil properties thereby affecting aggregate stability. The application of mineral fertilizer improved soil aggregation than control. *It is also evidence that the* application of organic base fertilizer, compost and compost – mineral fertilizer significantly ($p \leq 0.05$) improved the aggregate stability of soil compared to mineral fertilizer. And according to application of organic base fertilizer significantly ($p \leq 0.05$) improved the aggregate stability of the soil (*Bouajila and Sanaa, 2011)*.

Table 3: Effects of compost, compost - mineral fertilizer on Aggregate stability

Treatments	Aggregate Stability (%)
Control	1.80c
Urea	2.73b
NPK	2.96b
Compost	6.15a
Compost – Mineral Fertilizer	6.21a
LSD (0.05)	0.45

3.2 Fungi

The population and activities of soil organisms mostly fungi are increased with application of compost and other organic base fertilizer due to their high content of organic matter. Fungi isolated from plots treated with different fertilizers were fourteen and Aspergillus, Pennicillum and Fusarium were dominant. The control (zero application) had lowest isolates while the compost – mineral fertilizer had the highest isolates. A group researchers reported that when microorganism is incubated in the presence of two substrates, the variety of microorganism increases (Wang et al., 2019). Compost was prepared from combination of two or more type of waste sand these will enhance the number of fungi also the diversity of saprophytic microorganisms that play an important role in the biodegradation of such materials. The combination of inorganic and organic fertilizers significantly ($p \leq 0.05$) increased fungal colony forming unit (cfu) (48.0×10^3 and 40×10^5) compared to control, NPK and urea (Table 4).

Table 4: Total viable count of fungal isolates (CFU)

Treatments	Fungi 10^3	Fungi 10^5
Control	8×10^3	6×10^5
Urea	16×10^3	12×10^5
NPK	28×10^3	12×10^5
Compost	44×10^3	34×10^5
Compost Mineral Fertilizer	48×10^3	40×10^5

NPK fertilizer has been associated with increased biomass of fungi in soils of crop systems according (Aira et al., 2010). This might be attributed to the fact that organic manure supplied organic carbon / organic matter for the fungi which are chemo-heterotrophs. Fungi exhibits a wide range of

important ecological functions especially the ones associated with decomposition of organic substrates in soil. They are also valuable sources of by-products compounds and enzymes that can be of environmental importance (Jaber et al., 2012). The isolation of Aspergillus species from compost has been reported (Rabia et al., 2007). They reported that the highest load and number of species of Aspergillus and Penicillium are found in compost. The finding was in agreement with these results that the number and diversity of microorganisms are more when two or more waste was used for composting (Storm, 1985). The abundance of Penicillium can be attributed to its universal presence as a saprophyte growing on dead leaves, woods, and other decaying vegetation.

Table 5: Fungi isolated from Plots Treated with Different Fertilizers

Treatment	Fungi Isolates					
Control	*Aspergillus Spp.*	*Nigrospora Spp.*	*Penicillium Spp.*			
Urea	*Alternaria Spp.*	*Collectorichum Spp.*	*Fusanium Spp.*	*Nigrospora Spp.*		
NPK	*Aspergillus Spp.*	*Bipolaris Spp.*	*Chaetomium Spp.*	*Oidium Spp.*	*Phoma Spp.*	
Compost Mineral	*Aspergillus spp.* *Nigrospora Spp.*	*Oidium Spp.* *Fusarium spp*	*Phoma Spp.*	*Rhizoctoria Spp.*	*Septoria Spp.*	*Penicillium spp*
Compost	*Fusarium spp* *Phoma Spp.*	*Scopulariopsis spp*	*Aspergillus spp*	*Arthoconidia spp*	*Rhizoctoria spp*	*Penicillum spp*

The spores are widespread and are often associated with organic materials and soil. Fusarium species were also isolated from the organic base fertilizers and According to Fusarium species are widely distributed in all soils and are responsible for the decomposition of organic manure by their growth hyphae and are regarded as imperfect fungi (Giovano et al., 2005). Fungi play important roles as decomposers, plant symbionts and pathogens in soils. The structure of fungal communities in the rhizosphere is the result of complex interactions among selection factors that may favor beneficial or detrimental relationships (Berendsen 2012).

According to the combine application of organic and inorganic fertilizer enhance the population and activities of fungi and other organisms and this report corroborate with the results obtained from this study (Wang et al., 2017). Microorganisms such as fungi cause favorable transformations in soil, optimizing the living environment, growth, and yield of plants. Positive effects on yield and plant healthiness after application of organic manure was reported in the work (Kowalska, 2016). Apart from transformation of soil organic matter, fungi are also involved in the improvement of soil structure and pH. Soil microorganisms detoxify many chemical compounds which are harmful to other organisms living in the environment, and they eliminate pathogenic organisms (Niewiadomska, 2013).

4. Conclusion

The application of fertilizer increased the nutrient status of the soil. However, the application of compost – mineral fertilizer significantly increased organic matter and the nutrient status of the soil compared to other treatments. Compost and compost – mineral fertilizer increased the pH of the soil to near neutral; hence compost base fertilizer can be used as liming material. Compost and compost – mineral fertilizer application significantly ($p \leq 0.05$) increased the aggregate stability of the soil compared to other treatments. The incorporation of compost and compost – mineral fertilizer increased fungi population and diversity in the soil.

Acknowledgement

I wish to acknowledge the Tertiary Education Trust Fund (TETFUND) for the financial support to formulate, prepared the compost - mineral fertilizer and to carry out this experiment.

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