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Assessment of Soil Physicochemical Properties Under Contrasting Earthworm (Keffia Nigeriense) Management Practices

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A B S T R A C T

Soils of south eastern Nigeria are generally characterized by low fertility and structural defects due to high erosivity and poor management practices. Earthworms are most important soil organism in terms of their influence on plant litter decomposition, nutrient cycling and availability of resources for some other soil organisms, but detailed study on these roles have received very little attention in the study area. This study was therefore an attempt to assess changes in soil physico-chemical properties as induced by Keffia nigeriense (Kn) activities. Two earthworm conditions, Keffia nigeriense cast (Kc), earthworm habitat {soil under Keffia nigeriense activity (Ksi)} and a control {soil outside the area of Keffia nigeriense activities (Kot)} were studied. Composite soil samples were taken from 0-5cm soil depth from the earthworm habitat and control. To determine the quantity of earthworm cast produced a wooden quadrant was used for the daily collection of earthworm cast. The physical and chemical properties were analyzed and the characteristics of both the soil and casts described. The result of the study showed that daily earthworm cast production varies from 0.120 – 0.603 tha^{-1} day^{-1} when daily evapo transpiration was minimal 0.3 – 0.6mm/cm^2. Kn activities increased the soil total porosity by 7 % and decreased soil bulk density by 8 %. The buffering capacity and pH result showed a trend of Kc > Ksi > Kot, the CEC of the soil increased 3 folds and electrical conductivity 8 folds with Kn activities compared to where there is no Keffia nigeriense activity. The soluble mineral cation values of the soil under Keffia nigeriense activities was 100% and the casts value was 569.6%. The earthworm worked soil (casts) recorded the least value in exchangeable acidity but with highest value of base saturation among the treatments. The result of this study showed that Keffia nigeriense is very effective in plant nutrient release and amelioration of soil physicochemical properties, therefore proper culturing and study should be intensified in the studied area with a view to promote soil fertility and crop performance.

Keywords: Earthworm, Keffia nigeriense, Soil properties, Crop.

INTRODUCTION

Soils all over the world have been able to maintain continuous existence of life on earth due to certain soil organism such as termites, ants and earthworms which work in association and contribute immensely towards maintaining its stability and productivity. They have been identified as the most important soil engineers[1], or ecosystem engineers. The reason for this term-engineers, being the ability of these organisms to move the soil and through the soil as well as the ability to build up organo-mineral structures that have specific chemical, physical and biological properties. The bioorganic structures build up by these organisms are referred to as casts, fungus comb chambers, mounds or galleries[2]. Among all these organisms, earthworms stand distinctly out due to its paramount influence on soil characteristics.

Earthworms are marvelous in their ability to improve soil structure, soil microbes, soil physicochemical characteristics and plant growth[3-14], through the tunnels they make beneath the soil which aerate the soil, allow water permeability and infiltration and organic nutrients deep down into the soil, where the roots of the plants inhabit or reside. According to Mba[15], they can be regarded as natures plough through the process; they transform soils with compact structure to a spongy porous structure, thereby making agricultural activities possible on such soils. In wide variety of soils, climates and diets, earthworms are involved directly or indirectly in bio degradation, stabilization through humus formation and various soil processes[16,17,14]. There are greater amount of plant nutrient release through their exclusive feeding habit and casting activities[14].

The decomposition of organic matter and incorporation of plant residues in the soil horizons by a given earthworm species and its influence on soil characteristics depends on that species life history, the climate and environment the organism is found. For instance the endogeic earthworms feed on pieces of organic litter and mix it thoroughly through the surface mineral soil[18,19], because most of their activities are confined to surface soil horizons, hence their effectiveness to water infiltration and permeability are limited. Aneceic earthworms are deep burrowers as they make large vertical burrows that facilitate water transport, nutrients and agricultural minerals into deeper soil layers, also from deeper soil horizon, they bring soil to the surface, which over time can change the mineralogy of the surface soil[1,20,21], while the epigeic species are very much active in the breakdown and mineralization of the plant litter. The Keffia nigeriense (Nigeria earthworm), belong to the class of aneceic species of earthworm. They make vertical burrows, deeper into the soil, casts liberally on the soil surface, depositing their casts within the burrows and in some cases their casts persist on the soil surface, even after the organism have died or moved out to another environment. Therefore through the casts formed from plant litter present in a particular location, earthworms greatly influence the physical, chemical and biological activities in the soil. Their biomass production and fecundity are important factors to be considered in order to promote earthworm survival, population density and activities in the soil in order to harness earthworm potentials for food security at this era of organic farming. It was based on this background that this study was undertaken to evaluate the quantity and quality of the surface earthworm cast produced by Keffia nigeriense (a Nigeria earthworm) in a field plot and its influence on soil characteristics.

MATERIALS AND METHODS

Location of the experiment

The study was carried out at Anambra State University Igbariam Campus Anambra State, Nigeria. The study area lies between latitude 06 14'N and longitude 06 45'E. The rainfall pattern is bimodal between April and October, with a mean annual rainfall of 2500mm. The dry season falls between November and March. The relative humidity (RH) of the study area is moderately high all year round with the highest RH of 85% during the wet season and the lowest 64% occurring during the dry season and temperature range is between 21^{oC} – 35^{oC}. The plants/weeds commonly found in the lawn of the study area are *Talianum triangulare, cynodon dactylon, Tridax procumbers, corchorus tridents, mitracarpus villosus, Gomphrena celosioides,* while Table 1 presents the physical and chemical properties of soil in the study area.

Field work

A wooden quadrant of dimension 90cm x 45cm was used to determine the daily cast production and collection. Soil cores were taken with cores of 5.5cm diameter by 5cm for bulk density, total porosity and pore size distribution determination. The evapo transpiration of the site was also determined. Composite soil samples were taken from 0-5cm soil depth for the study of physical and chemical properties of the soil.

Laboratory method

Particle size distribution was conducted using sodium hexametaphosphate as dispersant and hydrometer method as described by[22], while the soil textural class was determined using USDA textural triangle. Bulk density was determined by core method according to[23]. The method described by[24] was used to measure total porosity. Total porosity was calculated from.

$$\text{Total porosity} = \frac{(Wsat - Wso)}{VT} \times 100\ \% \quad \ldots\ldots(1)$$

Where, Wsat = weight of soil at saturation.
Wso= Oven-dry weight of soil.
VT= Total value of core.

Chemical properties

The cation exchange capacity (CEC) was determined by un buffered barium chloride ($BaCl_2$) method of[25], soil electrical conductivity (EC) and soil pH in water were determined using the ratio soil water of 1:2.5 using a digital conductivity meter and a digital pH meter respectively. Soil buffering capacity was analyzed by determining soil pH using an aqueous solution of Ca $(0H)_2$ and then a solution of dilute H_2S0_4 and soil pH in water with the ratio solid: liquid of 1:2.5. Soil exchangeable acidity ($H^+ + Al^{3t}$) was analyzed by 1N KCL displacement method of[26]. Base saturation (BS) was calculated using:

$$\%\ BS = \frac{TEB \times 100}{CEC} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

While total dissolved cation was analyzed electronically using total dissolved solid digital meter.

Data analysis

The data generated from the study was subjected to the analysis of variance (ANOVA) test according to[27] and statistical significance difference was estimated using LSD at 5%.

RESULTS

The result in Table 2 showed the surface cast production of Keffia nigeriense. The cast production was observed to be high during the raining season and continued till the end of rainy season. Daily earthworm cast production at the peak of rainy season when daily evapo transpiration was minimal about 0.3–0.6mm/cm^2 varies from 0.120-0.603 tha^{-1}

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the cast is of ash brown in color and typically oblong in shape.

The total porosity and bulk density result in Table 3a differed significantly (P=0.05). The result obtained showed that earthworm activities increased the soil total porosity by 7% and decrease soil bulk density by 8% relative to the control soil where there is no earthworm activities while in Table 3b, the particle size distribution and textural class was not affected or influenced by the earthworm activities, though the silt content of the earthworm cast was found to be low compared to the result obtained in soil under the earthworm activities and soil outside the area of earthworm activities.

The results presented in Table 4 showed the effect of Keffia nigeriense (Kn) activities on soil chemical properties. The buffering capacity value showed that the Kn cast was highly buffered than soil under the activity of the Keffia (Ksi) and soil outside the area of Keffia activity (Kot), the order of increase is Kc > Ksi > Kot. The pH value was also observed to follow the trend of buffering capacity results. The activities of Keffia nigeriense (Kn) increased the CEC composition of the cast and soil under its activities and they were significantly different (P=0.05) from the CEC value obtained in soil outside the area of Keffia nigeriense activity (Kot). The soil net electrical charge in Table 4 was observed to be negative, for all the treatments, this suggests their ability to adsorb cations, store them and make them available to crops. The result of the electrical conductivity showed that earthworm worked soil (Kc) and the activity (Ksi) has a higher and favourable electrical conductivity and higher level of soluble cations.

The percentage increase in the electrical conductivity and soluble mineral cation values of Kc and Ksi relative to the value obtained in Kot were 570%, 569.6% (Kc) and 100%, 100% (Ksi) respectively. The result of the exchangeable acidity value showed significant differences among the treatments. The earthworm worked soil (Kc) recorded the least value but highest value of base saturation (BS) was obtained from the treatment while the least value of BS was obtained in the Kot. The nature of the result obtained in both exchangeable acidity and BS of Kc and Ksi, reflected the promotion of nutrient availability and favourable environment conducive for greater crop performance.

DISCUSSION

The efficiency of Keffia nigeriense (Kn) earthworm to promote soil conservation and productivity, physical and chemical properties of soil was particularly evident from the improvement in all the parameters assessed in this study. The level of water in the soil increases the activities of earthworm and determines the growth of earthworm; this may suggest the increased cast production observed which continued till the end of the raining season. Grant[28] observed that earthworm biomass consist of about 80-90% of their fresh weight as water and in a dry soil they will cease to grow and exhibit a phenomenon known as 'diapauses'. Similarly Nweke[14], reported that vermicomposts (cast) increased earthworm biomass, survival rate and cocoon size of Eudrilius eugenea. Cast production is a wonderful important product aspect of earthworm activities, as it can increase surface roughness reduce run-off erosion and increase infiltration rate that will lead to reduction in soil loss. For instance despite highly erosive rainfall in the studied site where the Keffia nigeriense activities are located, surface run-off erosion was nil. Kladivko *et al*.,[29] reported that earthworm increase surface roughness by casting on the soil surface and their burrowing activity can disrupt soil crust, which will further increase infiltration and reduction in run-off erosion. The Keffia nigeriense activity does not seem to affect the particle size distribution and soil

textural class of the studied area as the results obtained were at par with the control soil. However, the total porosity and soil bulk density results were enhanced by the activities of Keffia nigeriense. High soil porosity reduces run-off and soil erosion and also enhances soil moisture retentions, while low bulk density is desirable for easy penetration of plant roots and water infiltration in the soil. The increase in the soil porosity may be due to earthworm burrows and improvement in the soil aggregation as a result of feeding and mixing up of soil and plant litter that are deposited as cast in the burrows and at the surface of the soil. With these stable aggregates, and burrows, the earthworm tends to reduce the effect of soil compaction, increase in the water holding capacity of the soil and improve soil tilth. Hubbard *et al*.,[30] noted that earthworms play key role in modifying the physical structure of the soils by producing new aggregates and pores, which improves soil tilth, aeration, infiltration and drainage.

The impact of Kn activity on soil chemical properties were very remarkable. The soil CEC and buffer capacity increased more than 3-folds with Kn activity relative to the control soil. This indicates the presence of better quality ion exchangers in Kn worked soil. Soil ion-exchangers serve as multipurpose resource; they serve as deionizers, pH buffer systems, and anti-erosion and anti-leaching properties. Lee,[31] reported high concentrations of exchangeable calcium, magnesium and potassium in earthworm cast than the underlying soil due to the higher content of plant tissue in casts than in the soil. Nweke[14], similarly observed significant increase in CEC, available P exchangeable calcium and magnesium content in Bracharia and Andropogon vermicomposts following earthworm activities. Favourable biological activities in the soil that invariable will liberate plant nutrients need a stabilized pH because unstable soil pH disturbs biological activities in the soil. The result of the pH value obtained indicated that the pH of the earthworm cast (Kn) is closer to neutrality than that of the soil from which they are derived, this reflect favourable pH level for soil biological activities, nutrient release exchange and plant uptake. White[32] reported higher pH levels, available P, exchangeable Ca, OC% and mineral nitrogen in earthworm casts relative to non-cast soil. The electrical conductivity of earthworm worked soil increased favourably, which reflected mineralization and release of nutrient cations, the soil net negative electrical charge suggests their ability to adsorb cations, store them and make them available to crops. The earthworm worked soil showed the activity has a higher and favourable electrical conductivity and a higher level of soluble cations that is 8-folds greater than where there is no earthworm activity. Earthworm activities increase base saturation and decreased the exchangeable acidity, this reflects detoxification, nutrient availability and higher crop performance.

CONCLUSION

The findings of this study showed that the activity of Keffia nigeriense earthworm is very efficient and effective in ameliorating soil properties. The earthworm was found to enhance the soil physical and chemical parameters of the studied area. The soil porosity, bulk density, pH, buffer capacity, CEC, soluble minerals level, electrical conductivities were enhanced by the activities of Keffia nigeriense. These are worthy assets which can promote soil fertility, conservation and productivity. The findings of the present study are in line with the general concept that the activities of earthworm promote soil conservation and sustainable soil fertility status. It is therefore advised that the ecology of the Keffia nigeriense earthworm should be taken into consideration and intensifies study of the worm in the studied area in order to

harness its potentials with a view to promote soil fertility, conservation and crop production in the studied area especially now organic farming is the order of the day.

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Table 1. Physical and chemical properties of the soil of studied site

Clay%	22.31
Silt%	1.46
Sand%	79.09
Textural class	sandy clay loam
CEC $Cmolkg^{-1}$	3.91
Exchange acidity $Cmolkg^{-1}$	3.33
Electrical conductivity $Cmolkg^{-1}$	50
Buffer capacity $Cmolkg^{-1}$	0.320
Total porosity %	44.76
Bulk density gcm^{-3}	1.82

Table 2. Surface cast production by keffia nigeriense in field lawn during the peak of rainy season

Sampling days	$gha^{-1}day^{-1}$	$kgha^{-1}day^{-1}$	$tha^{-1}day^{-1}$	Evapotranspiration (mm/cm^2)
1	359,540.89	559.54	0.560	0.4
2	219,990.44	219.99	0.220	0.4
3	210,425.634	210.42	0.210	0.4
4	119,560.00	119.56	0.120	0.4
5	588,235.29	588.24	0.588	0.5
6	400,286.944	400.29	0.400	0.6
7	602,582.40	602.58	0.603	0.6
8	400,286.944	400.29	0.400	0.3
9	40356.385	403.16	0.403	0.3

Table 3a. Effect of Keffia nigeriense activity on top soil physical properties

	Total Porosity %	Bulk density gcm^{-3}
Ksi	47.99	1.62
Kot	44.76	1.82
LSD0.05	2.55	0.25

Ksi = Soil where there is Keffia nigeriense activity, Kot = Soil outside the area of Keffia nigeriense activities, LSD= Least significant difference.

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Table 3b. Soil particle size distribution and soil texture as influenced by keffia nigeriense activity

Sample	Clay%	Silt%	Sand%	Textural class
Kc	22.53	1.39	76.08	Sandy clay loam
Ksi	20.96	3.28	75.76	Sandy clay loam
Kot	22.31	1.46	76.09	Sandy clay loam
LSD0.05	NS	NS	NS	

Ksi =Soil where there is Keffia nigeriense activity, Kot = Soil outside the area of Keffia nigeriense activities Kc=keffia nigeriense cast, LSD = Least significant difference.

Table 4. Effect of Keffia nigeriense activity on soil chemical parameters

	Buffer capacity $Cmolkg^{-1}$	pH(H_20)	CEC $Cmolkg^{-1}$	Net electrical charge	Electrical conductivity µ s/cm	Soluble mineral cations $Cmolkg^{-1}$	Exchange Acidity $Cmolkg^{-1}$	Base saturation (%)
Kc	0.86	6.7	26.75	negative	335	0.84	0.8	99.7
Ksi	0.45	5.9	9.20	negative	100	0.25	0.58	93.72
Kot	0.32	5.6	3.91	negative	50	0.13	3.33	14.83
LSD=0.05	0.07	NS	1.35		25.7	0.09	0.27	1.18

Kc = Keffia nigeriense cast, Ksi=Soil under the activity of the Keffia nigeriense, Kot=Soil outside the area of Keffia nigeriense activity, LSD = Least significant difference.