International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET)

ISSN 2455-4863 (Online) www.ijisset.org Volume: 5 Issue: 3 | 2019

Utilization of Earth Worm Cast as Plant Nutrient Supplement for Alfisols in South West Nigeria

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Abstract: *It is well known that activities of soil fauna contribute to plant growth. Earthworm cast is one such natural product of soil fauna. This study was carried out to assess the nutrient supply potential of earthworm casts collected from selected vegetation covers in Ibadan, south west Nigeria.*

Earthworm casts obtained from Alfisols under vegetation covers of maize (MC), cassava (CC), oil palm (OPC) and a secondary forest (FC) from Ibadan, Nigeria were assessed for their fertilizing value using a test crop Amaranthus caudatus. Poultry droppings, mineral fertilizer (NPK 15-15-15) and soil alone were used as controls. Earthworm casts and poultry droppings as treatments were applied at the rates of 5, 10, 15 and 20 t ha^{-1}, while NPK was applied at 60kg N ha^{-1}. Effects of these treatments on soil chemical properties and growth parameters of the plant, viz. plant height, girth of the stem, number of leaves and the dry mass were studied.

Carbon and nitrogen contents of casts showed a range of 2.46-3.08% and 0.21-0.33%, respectively with no significant difference in nutrient composition of casts under various vegetation covers. Results of crop growth indicated significantly lower performance of various casts as compared to poultry droppings and NPK 15-15-15. Source of earthworm casts and type of vegetation cover did not show any significant difference on growth and yield of crop. However, earthworm casts under maize (MC) and from forest cover (FC) when applied at 20 tons per Ha showed a slight increase in the dry matter content of crop.

Keywords: Earth worm casts, Poultry droppings, NPK fertilizer, *Amaranthus caudatus,* Crop yield, Alfisol

1. INTRODUCTION

Humid Tropical soils are highly weathered, leached, characterized by low organic matter and dominated by low activity clay which is basically Kaolinite. This type of soil is known as Alfisol and it is one of the twelve soil orders (These are: Alfisols, Andisols, Aridisols, Entisols, Gelisols, Histosols, Inceptisols, Mollisols, Oxisols, Spodosols, Ultisols, and Vertisols) in USDA [1]. These type of soils are arable, enriched with subsoil of clay, very fertile and sustains water for at least three months even in dry season and are covered with natural broad-leaved deciduous forest vegetation and sometimes interspaced with grasses. There is the need to address such soils for long term management for maximum and sustainable crop yields because of their wide use in agriculture and forestry and high ability to retain her fertility than other soils. The main crops cultivated on Alfisols are corn (maize), wheat and even wine grapes, hence representing the soil order for food and fiber production [2]. Consequently, maintenance of soil fertility in the humid tropics is an essential aspect of agronomic priorities.

From time immemorial earthworms played an important role both in ecological and agricultural sustainability. They maintain and enhance soil fertility and crop production though their effect on soil organic matter incorporation, decomposition and associated nutrient cycling especially by bringing to the surface casts that are higher in nutrient composition than the adjacent soil [3a,b,4,5]. Earthworm activities such as burrowing also promote soil physical properties such as structure, water infiltration, aggregate stability and porosity; facilitating plant roots penetration into the subsoil.

Soil organic matter is the means whereby agriculture has been able to recycle, replenish, review and provide the nutrients necessary for plant growth [6]. Its beneficial effect on the physical and biological properties of soils has also been well documented. In tropical soils, organic matter has been described as being synonymous to soil fertility [7] and thus considered as a representative index of the fertility of soil [8].

The pioneering work of Darwin [9] established the importance of earthworms as major influence on the fertility of the soil. Hence, the role of earthworms in the incorporation and decomposition of plant material and in the improvement of soil physical properties and nutrient status has received attention [10]. It is clear from the studies of Lee [11] that the decomposition of earthworm casts improves soil organic matter and that earthworms dominate the biomass of soil macro fauna in the humid tropics [12].

From agricultural point of view, earthworms may be classified into groups: the family Lumbriade and the other families belonging to the suborder of the order Oligochaeta. The living habits of the different species of earthworm differ appreciably. Many feed on surface litter, some coming to the surface to collect it and then drag it down into their burrows and others only pulling down the litter that is directly above their burrow. They typically consume soil along the plant debris [13]. Hence, earthworms where they flourish, as in virgin soil and pastures, are the principal agents in mixing the dead surface litter with the main body of the soil thus making it more accessible to attack by the soil microorganisms. Thus in the soils where there is abundance of earthworm populations, the tendency of improved soil nutrient status is likely.

Seasonal variation influences earthworm activities and their populations [14, 15]. Casting activity is known to be influenced by variation in soil temperature, soil moisture and food supply [3b, 16]. Some species of tropical earthworms however, may cast considerably greater quantities of soil on the surface. [17] found two species producing greater quantities of soil on the surface. He further observed that two species producing about 170 ton ha^{-1} of casts during the two six months wet season in some western Nigeria pastures in Ibadan. Other workers reported different quantities of casts. [3a] recorded 30 ton ha^{-1} per year, [18], 75 tons ha-1 per year in a cassava field on Alfisol, while 42.8 tons ha^{-1} per year in an alley cropping system with *Leucaena leucocephala* as hedge row.

The concentration of plant nutrients is usually greater in the earth worm casts than in the parent soil [19, 3b, 20, 15]. The earthworm casts collected on the Ultisol under a 'puraria cover' showed 3.7% C and 0.43% N [20] and to those collected on Alfisol showed, respectively 2.5% and 0.24% [18], 3.8%C and 0.38% N [4] and 5.2% C (N was not determined; [15]).

The levels of Ca, Mg and K were substantially low in the casts. Work reported by [20], showed the cation content of casts collected on the Ultisols under 'puraria cover' crop was carbon 80, magnesium 35 and potassium 7 meq Kg –1. The corresponding soil cation contents were 22, 12 and 2.4 meq Kg^{-1} soil for Ca, Mg and K respectively. The above findings coupled with the micro-climatic conditions of south west Nigeria where rainfall continues through eight months of the year maintaining optimal soil moisture level promote earthworm activities. The soils under various vegetation covers show large quantities of earthworm casts during the wet season. It will be interesting to know whether these casts vary in their potential nutrient supply to the soil. One of the challenges facing tropical agriculture is the need to make best use of soil organic matter for improving the nutrient status of the poorly buffered tropical soils. The higher nutrient and soil organic matter contents of earthworm casts than the non-ingested soil [19, 11] prompted the use of earthworm casts in soil amendments. It is with this background a study was carried out.

Amaranthus, a staple green vegetable in Nigerian diet appears to do well on a wide range of soil types, from very acidic high aluminium soils to alkaline and saline soils. There is a wide range of tolerance among the genotypes. They are adapted to fine to coarse soils depending on the drainage conditions [21]. Thus, this plant was used as test crop under green house conditions. The aim of this study was to determine the nutrient quality of earthworm casts collected from different land use systems and to assess their utilization for growing green amaranth (*Amaranthus caudatus*) as a test crop.

2. MATERIALS AND METHODS

The experiments were conducted in the green house of the Department of Agronomy, University of Ibadan, Nigeria between November and January, and the end of rainy season and before the onset of dry season.

Earthworm casts from vegetations under maize, cassava, oil palm and a secondary forest on the Alfisols of University of Ibadan, Nigeria were collected and used as treatments. The earthworm casts were collected from soil that had been continuously under cultivation for about 15 years and a secondary forest of more than 15 years. The nutrient or fertilizing potential of earth worm casts was also compared with poultry droppings collected from a poultry farm on the campus, mineral fertilizer (NPK 15-15-15) and soil alone with no fertilizer acting as controls. The experimental soil was collected from a land under 15 years of exhaustive cultivation within the same institution (Table 1). Poultry used was collected from layer birds. The test crop was green amaranth, *Amaranthus caudatus*.

The experimental design is a 5 by 4 factorial type. The factors were the four earthworm casts and the poultry manure at four rates of application: 5, 10, 15 and 20 t ha^{-1}. The NPK applied at 60 Kg N ha^{-1} and soil alone was used as the control treatments. The treatments were replicated thrice in a completely randomised design. Two Kg of soil per pot was mixed thoroughly with the fertilizer under treatment. The casts were ground before adding to the soil. Amaranthus seeds were sown by broadcasting and thinned to two plants per pot, a week after germination. Every other agronomic practice was observed for proper management of the plants.

Laboratory analysis was carried out to determine both physical and chemical characteristics of the experimental materials and appropriate statistical analysis was carried out to analyse the various parameters observed during the experiment.

3. RESULTS AND DISCUSSION

3.1 Nutrient composition of the earth worm casts

Earthworm casts collected from maize, cassava, oil palm and secondary forest had pH range between 5.87 and 6.54 which is rated as medium and preferred for most crops as classified by [22].

ISSN 2455-4863 (Online) www.ijisset.org Volume: 5 Issue: 3 | 2019

The low value of Carbon (C) in earthworm casts collected under cassava based cropping system could be as a result of continuous disturbance of the soil which reduces the activity of earthworms and subsequent increase in decomposition which results in release of C as CO_2 . However, the higher value in the casts collected under maize cropping system could be due to the return of the crop residues into the soil and the application of inorganic fertilizer which enhanced the production of biomass. The casts from oil palm had a higher value than the casts collected under cassava based cropping system could be as a result of the low disturbance of the soil. Low soil disturbance and leaf litter fall in the secondary forest could be the reason that may be advanced for its higher C or organic matter status. This assertion agreed with the findings of [23].

The C and N contents of the casts collected under secondary forest (38.70g kg^{-1} and 3.70 g kg^{-1} N) were similar to those collected on Alfisols by [4] with 38.0 g kg^{-1} C and.3.80 g kg^{-1} N, while the ones collected from cassava field (25.00 g kg^{-1} and 21.00 g kg^{-1} N) were similar to the ones collected on an Alfisols by [18] with 25.00 g kg^{-1} C and 2.40 gkg^{-1} N. The C and N content of the earthworm casts collected from maize based cropping system (34.00g kg^{-1} C and 3.00 g kg^{-1}N) were similar to the ones collected under maize field of two years of cultivation by [23].

The Ca, Mg and K content of casts however, were substantially lower in the cassava and secondary forest casts (65, 26 3 C mol kg^{-1} and 85, 23, 5 C mol kg^{-1}) compared to 160, 32, 8 C mol kg^{-1} [15] on the Alfisols. Also, Ca and K (100, 31 C mol kg^{-1} 60, 45 C mol kg^{-1}) contents were lower for casts collected from maize and oil palm fields as compared to 178 and 22 C mol kg^{-1} on Alfisols. The K contents of (8 and 3 C mol kg^{-1}) are higher for maize and as compared to those from oil palm which showed 6 C mol kg^{-1}[18]. These variations could be due to the difference in the organic materials ingested by the worms and the nature of the parent material.

The cations exchange capacity (CEC) of the earthworm casts could be rated as low according to [24] classification. Soil analysis after cropping revealed that earthworm casts collected from maize, cassava, oil palm and secondary forest increase the CEC of the soil by 15.8, 13.5 , 14.2 and 13.5% respectively compared to 27.9% increase by poultry manure. This could be due to the low organic matter content of the earthworm casts with the assertion that organic matter increases soil CEC [25, 26].

Plant height of amaranthus increased with the rate of application with the exception of cassava and oil palm casts. The increase could be attributed to increase in the amount of nutrients with the rates that could sustain or meet the demand of the crop.

In all the treatments, cassava cast promoted the lowest value of plant height probably due to the fact that earthworms burrow deep down into the soil profiles where cassava roots extracts most of their nutrients. In addition, microbial populations differ from one earthworm cast to the other depending on the prevailing conditions such as temperature, moisture and the amount and type of organic matter. The microorganisms on the onset of decomposition will feed on the available nutrients in the soil and they multiply during the passage from the foregut to the hindgut. It was shown that they multiply about 1,000 times in the casts than in the organic materials in the soil.

Means having the same letter are not significantly different (p=0.05) using Duncan's Multiple Range Test.

Stem girth, leaf number and leaf area of amaranthus increased with the rate of application for both the poultry manure and earthworm casts except for cassava and oil palm casts. This may be attributed to the nutrient status of the earthworm casts.

Rate of height, stem girth, leaf number and leaf area increase recorded at 3WAP for poultry manure might have resulted from the highest rate of mineralization of nutrients as reported in the study of [27]. However, low nutrients coupled with high number of microorganisms might have utilized most of the nutrients in the early stage of plant growth. At 5 and 6WAP when most of the growth parameters showed their maximal rate of increase coincides with the time when the immobilized nutrients by the micro-organisms may have been mineralized and further degradation of difficultly degradable part of the organic matter commenced. The increased yield at higher rates of treatment application is a reflection of the nutrient content of the casts. The same may also be applicable to organic material when used for soil fertility restoration as reported by [28]. With this trend, fresh air-dried poultry manure induced early growth while earthworm casts did at later stages and with higher rates of application.

The dry matter yield indicated the dependency of amaranthus on the nutrient availability and also quantity. It can therefore be inferred that growth of amaranthus like any other plant will require N, P, K, Ca, and Mg to a great extent than Na.

Poultry manure and the earthworm cast increased the CEC of soil to varying degrees. Stem height, stem girth, leaf number, leaf area and dry matter yield of amaranthus showed no significant difference between the casts as well as the rates.

In conclusion, casts produced under undisturbed vegetation or where produced under organically rich soils can be a good nutrient source for plants. Furthermore, if these are obtained from organically rich soils, they can be good nutrient sources for plants when applied in combination with poultry manure or inorganic fertilizer. Therefore, given the strong

ISSN 2455-4863 (Online) **www.ijisset.org** *Volume: 5 Issue: 3 | 2019*

enrichment of nutrients in the casts, it can play a great role in soil fertility restoration.

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TABLES

Table 1: *Physico-chemical Properties of the soil used in the experiments*

Characteristic	Value
pH (1:2 soil: water)	7.00
Total Carbon, g kg^{-1}	3.90
Organic Matter, g kg^{-1}	6.20
Total N, g kg^{-1}	0.30
Available P (Bray's P1), mg kg^{-1}	2.43
Exchangeable, (C mol kg^{-1})	
K	0.08
Ca	1.15
Mg	0.51
Na	0.33
Exchangeable Activity	0.08
CEC, (C mol kg^{-1})	2.15
Sand, (g kg^{-1})	9.38
Silt, (g kg^{-1})	20
Clay, (g kg^{-1})	41
Texture class	Sandy

Table 2: *Chemical Properties of poultry manure*

Characteristic	Value
pH (1:2 waste: water)	7.45
Total Carbon, (g kg^{-1})	197.60
Organic Matter, (g kg^{-1})	341.70
Total Kjeldahl N, (g kg^{-1})	17.10
Available P (Bray's P1), mg kg^{-1}	1.70
Exchangeable cations, (C mol kg^{-1})	
K	38.36
Ca	4.00
Mg	9.65
Na	8.70

Table 3: *Nutritional characteristics of the earthworm casts*

Earthworm cast obtained from	pH 1:2 Soil: water	C %	Organic matter %	TKN %	P mg Kg^{-1}	K	Ca	Mg	Na	Exch. Acidity	CEC
						(cmol kg^{-1})					
Maize	6.52	3.44	5.95	0.30	37.18	0.82	10.0	3.12	0.32	0.08	14.3
Cassava	6.52	2.46	4.25	0.21	4.19	0.36	6.5	2.60	0.32	0.16	9.9
Oil Palm	5.87	3.03	5.24	0.26	9.46	0.31	6.0	4.49	0.32	0.08	11.2
Secondary forest	6.54	3.08	6.57	0.33	29.74	0.49	8.50	2.30	0.24	0.08	16.61

Table 4: *Effect of poultry manure, earthworm casts and inorganic fertilizer on dry matter yield* of Amaranthus caudatus (g pot^{-1}).*

Treatment	Rate of application (ton ha $^{-1}$) and the Dry Matter Yield			
	5 tons	**10 tons**	**15 tons**	**20 tons**
Poultry droppings	3.53^{c}	5.42^{b}	6.14^{b}	8.03^{a}
Earth worm cast under maize (MC)	0.22^{d}	0.45^{d}	0.54^{d}	0.70^{d}
Earth worm cast under cassava (CC)	0.12^{d}	0.14^{d}	0.59^{d}	0.11^{d}
Earth worm cast under oil palm (OPC)	0.64^{d}	0.12^{d}	0.58^{d}	0.12^{d}
Earth worm cast under Forest Cover (FC)	0.28^{d}	0.72^{d}	0.50^{d}	0.54^{d}
NPK Fertilizer	2.64^{c}	-	-	-
Control soil	0.31^{d}	-	-	-