

THE ROLE OF EARTHWORMS IN SOIL STRUCTURE, NUTRIENTS CYCLE AND VERMICOMPOSTING

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Corresponding author: ayahya20@yahoo.com**ABSTRACT**

Earthworms can alter soil environment by changing soil properties. They have great potentiality to enhance soil physical properties, mineralization of nutrients, heavy metals bioavailability, and land remediation. Similarly, many studies have shown that organic matter inputs in compost or vermicompost produced in the presence of earthworms are valuable soil amendments which increased plant growth. Earthworms are now widely being use as waste mangers, composting of food and farm wastes, and soil mangers for "fertility improvement". However, very little is known about the negative effects of earthworms in the soil ecosystem, their role in extreme environmental conditions and species of earthworms with strong resistance to heavy metals. So this paper was reviewed to explore the role of earthworm as soil and ecosystem engineer. This was already established fact but main aim of this paper is to collect the related information and conclude the future research prospects to strengthen the earthworm role as soil and ecosystem engineer. We also recommend the use of earthworms and vermicomposting in Nigeria, for effective waste management and soil amendments.

Keywords: Earthworms, Waste Management, Land Remediation, Vermicompost.**INTRODUCTION**

Earthworms are classified within the phylum Annelida, class Oligochaeta, and order Opisthophora. In spite of the fact that, there is not universal agreement on taxonomic classification, up to date analyses has shown 16 families, 6 comprising aquatic or semiaquatic worms and the other 10 consisting of the terrestrial forms (Lavelle, 1983). There is a wide range of diversity among the earthworm fauna, more than 3500 earthworm species have been described and a lot more still awaits discovery and description (Edwards, 1995). Earthworms are distributed worldwide in different habitats where soil water and temperature are favourable for at least part of the year, they are copious in forests and grasslands of

temperate and tropical regions and least in arid environments. Throughout this habitat range earthworms shows a wide range of morphological, physiological and behavioural adaption to environmental conditions (Lee, 1985). According to their habitat types and ecological functions, earthworms can be divided into three types: the epigeic, the endogeic, and the anecic. However, sometimes the boundaries among the ecological groups are not so clear, with the occurrence of some transitional types (Ismail, 1995). The Epigeic species feeds on the upper surface while endogeic made the permanent deep burrows. Anecic species lives near subsurface soil region. They have their own morphology and have own feeding system. Epigeic

species mostly feed on plant debris. So, they are mostly responsible for breaking down complex organic residues and mineralize nutrients (Bouche, 1972).

Earthworms are the most familiar and, with respect to soil process often the most important of the soil fauna (Edwards, 1995). Earthworms are integral part of the soil organisms in almost all global soils, they exhibit a notable proportion of the soil biomass and are considered as a useful indicator of soil health and quality (Edwards, 2004). The importance of earthworms arises from their influence on soil structure, regulation of soil biological and physico-chemical properties (Lavelle, 1997). Earthworms provide a wide range of essential ecosystem services, such as the maintenance of soil fertility through the decomposition of organic matter, the cycling of carbon and nitrogen and other nutrients, advancement of soil structure for erosion control, water storage and enhancement of water flow (Lavelle and Spain, 2001; Lavelle et al., 2006). The activities of earthworms show crucial influences on two necessary soil functions, soil organic matter dynamics and microbial activity (Lavelle, 1988). These impacts on ecosystem functioning explain the increasing interest in using earthworms for the sustainable management of agro-ecosystems as well as the rehabilitation of degraded and polluted lands.

This paper will highlight the importance of earthworms in soil structure and function, nutrients cycle, vermicomposting, remediation of degraded polluted lands and waste management. We recommend areas for further research and effective utilization of beneficial effects of earthworms in a developing country like Nigeria.

Effects of earthworms on soil structure and mineralization of nutrients

Earthworm plays a very important contribution to soil structure, through their feeding, burrowing and casting, they profoundly change soil physical, chemical and biological properties (Satchell, 1983). For instance, by making burrows, earthworms

magnanimously influence soil structure and therefore modify soil transport characteristics (Je'gou et al. 2000). One of the most significant contributions is its role in the formation of soil aggregates. Blanchart's (1992) had indicated in a field test that damaged soil aggregates in tropical grassland can be restored by earthworm (*Megascolecidae*) greatly. He further revealed that soil not inoculated with earthworm contains 12.9% macro aggregates (>2 mm) after 30 months and that inoculated with earthworm contains 31.7% macro aggregates after 6 months and 60.6% after 30 months. The study has also shown that aggregates formed by earthworms have higher water stability. The activities of earthworms have also resulted in the formation of many organic mineral complexes, which increase the content of water stable aggregates with >1000 μm diameter (Ketterings et al. 1997). Recently Bossuyt et al. (2005) also revealed that carbon is combined into stable soil aggregates with activities of earthworm, thereby increasing the stability of aggregates and making soil organic matter easier to decompose. The activities of earthworms have also been reported to significantly change the physical and chemical properties of soil which further enhanced the mineralization of organic matter and stabilize soil nutrient cycles (Parkin and Berry, 1999).

Earthworm has significant effects in the cycling and transformation of soil nutrients through its influences on soil physical, chemical and biological properties. The activities of earthworms have been shown to raise the availability of soil nutrients and the rate of nutrients cycles (Basker et al. 1992). For instance, Edwards, (2004) found that when organic materials and soil pass through the stomach of earthworms, calcium, humic acid, plant residues and polysaccharide will be glued together and form earth feces, which are loose and porous and gave the advantages of strong water stability, suitable availability of nutrients and high capability of nutrient sustenance. Earthworm activity also enhances the fragmentation and humification of coarse particulate organic matter into finer fractions and influences the

distribution of organic matter (Martin, 1999). The bodies of earthworms have been reported to contained strong active nutrients sources, their bodies will be completely decomposed in 4 days after death and 70% nitrogen in the bodies will be taken up by plants after 16 days (whalen et. al.1999). Several studies have demonstrated that the soils refined by earthworms often have higher values of organic matter, total N,Ca, Mg, and K, available N and P etc. (Cortez et. al. 2000). For example, the contents of mineral nitrogen ($\text{NO}_3\text{-N}+\text{NH}_4\text{-N}$), total carbon, nitrogen and microbial biomass in stalk-returning soils with rotation of paddy and wheat are significantly enhanced after the soils were inoculated with earthworms, indicating that earthworms have dual functions of increasing soil microbial biomass and promoting the mineralization of organic nitrogen (Li et. al. 2002). Earthworms also release nutrients to soils directly through their metabolic activities. Amador et. al. (2003) estimated that the organic nitrogen released by dead earthworms reached to 21.1-38.6 t ha^{-1} every year.

Effects of earthworms in heavy metals bioavailability and land remediation

Owing to rapid industrialization, the problem of soil heavy metal pollution becomes increasingly serious. The heavy metal pollution not only degrades soil quality but also threatens the safety of agricultural products and thus does harm to human health (Suthar, 2009). Earthworm is of the most important soil animals that affect soil properties. It can directly influence the chemical behaviours of heavy metals in soils through feeding, burrowing, excreting casts, or other metabolic activities (Yang et. al, 2007). It is well established that earthworms influence metal mobility in soil through their burrowing and casting activity and also that action of earthworm strongly affects the distribution and activity of soil microorganisms. These microorganisms can modify heavy metals speciation and metal/organic matter interaction by transformation of organic compounds,

enhancing heavy metals bioavailability for plants (Giller et. al, 1998). Devliegher and Verstraete, (1996) has also reported that heavy metals contaminated soils after treatment with earthworms, changes significantly the fraction distribution of heavy metals thereby affecting their bioavailability.

The pH is one of important factors to affect bioavailability of heavy metals in the soil. Earthworm's activities can influence bioavailability of heavy metal by changing soil pH. pH of soils inoculated with different kinds of earthworms is significantly different. For example, the pH of acidic red soil declines by 0.03-0.18 when it is inoculated with earthworms in contrast, pH of a sandy soil with the same treatment is only slightly enhanced (Yu and cheng, 2003). Similarly the pH of cock manure has been shown to have decrease by 0.7-0.9 after it was inoculated with an earthworm *Eisenia foetids* (Yang et. al, 2007).

Application of earthworms in vermicomposting, waste management and plant growth

Vermicomposting is the use of earthworms for composting organic materials which produce excreta known as casts, and the recent biotechnology provides biofertilizers in the term of vermicompost (Edwards, 1995). Vermicompost technology has been widely applied in organic waste management, industrial and municipal waste water management, and treatment, clean up contaminated lands, fertility improvements and enhancements of farm production (Sinha, et-al. (2010). Vermicomposting facilities has been reported to be in commercial operation in Japan, Canada, and U. S. A. and is also being efficiently practised in the Philippines and in Asia (Ghosh, 2004).

Vermicomposting has been used for agricultural and high quality protein (earthworm biomass) for supplementing the nutritional energy needs of animals, at a faster rate. Vermicomposts, specifically earthworm casts, are the final product of vermicomposting. It is an aerobic, biooxidation and stabilization non-thermophilic process of organic waste decomposition that depends upon earthworms

to fragments, mix and promotes microbial activity (Gaundi, 2002). The utilization of vermicompost, which involves the activity of epigeic earthworms in controlled environments, appears as an indirect avenue for gaining beneficial effects from earthworms. Vermicomposting is an alternative technology to traditional composting and purely mineral fertilization (Edwards and Arancon, 2004). During the process of vermicomposting, important plant nutrients such as nitrogen, potassium, phosphorus and calcium present in the feed material are converted through microbial action into forms that are much more soluble and available to the plants (Ndegwa, 2001). Vermicomposting has been used as an organic fertilizer because it is characterized by a high content of plant available nutrients (N,P,K) (Edwards and Arancon, 2004). The studies on the effects of vermicomposting on some components of organic waste showed that vermicompost enhances degree of polymerization of humic substances along with a decrease of ammonium N and an increase of nitric N (Gegarra, 1992).

Researchers have explored an enormous variety of agricultural and municipal wastes as potential feedstock for vermicomposting. Various organic waste have been tested in the past as feed material for different species of earthworms include sewage sludges (Mitchell et al. 1980; Benitez et al. 1996), combined sewage sludge and municipal refuse (Grappelli et al. 1983), paper mill industry sludge (Butt 1993), pig waste (Reeh, 1992), paper waste (Gajalashmi et al. 2001), cattle manure (Sagar et al. 2002), industrial and vegetable waste (Elvira et al. 1999). Others includes horticultural waste, animal waste, silkworm litter, plant biomass (leaf litter), weeds, kitchen waste abiding, foul, acidic, spicy and spoiled food, city refuse after removing non-degradable waste such as glass, plastic, strong rubber and metal can be vermicomposted (Kale, 1995).

The compost produced by vermicomposting of organic waste has been widely applied to agricultural lands to improve soil structure and

fertility for the growth of plants. The importance of vermicompost in agriculture and plants growths has been reviewed by many workers. For instance, it has been long established that earthworms (vermicompost) prepare the ground in a manner for the growth of fibrous-rooted plants and for seedlings of all kinds (Darwin, 1881). Nielson, (1965) has earlier showed that earthworms (vermicompost) also produced certain beneficial metabolites, vitamins and similar substances into the soil (B and D group vitamins) which enhances plants growths. Vermicompost has been found to be an ideal organic manure enhancing production of a number of crops (Vasudevan, 1997; Hidalgo, 1999).

Plants dry weight and nitrogen uptake has been shown to increased due to application of vermicompost, (Tomati, 1994; Edwards, 1995). The application of vermicompost has been showed to increased protein synthesis by 30% in *Lactuca sativa* seedling (Galli, et. al. 1992). Vincelas and Loquet, (1997) compared the effects of composting and vermicomposting lignocellulosic maple waste and reported that the vermicompost product had a lower C/N ratio, higher protein:organic C ratio, and higher levels of N, which indicates that the vermicompost products were more suitable for soil amendment and plant growth. Similarly, study by Dominguez, (1997) vermicomposted pig manure and observed 50-60% higher nutrients in earthworm treatments than in the control. More so, vermicompost in experiments with tomatoes and cabbages in Poland has showed to protect these vegetable plants from a number of microbes' diseases (Szczecz, 1994). This however has provided its suitability for use as pesticides, for the control against microbial diseases in vegetable plants.

Other beneficial effects of earthworm cast utilization in other horticulture settings have also been reported (Hidalgo, 1999). Fresh casts often contain ammonium levels, but rapid nitrification results in stable levels of both nitrogen forms due to organic matter protection in dry casts (Decaens, 1999). Earthworms are known to act as vector of viable

propagules of mycorrhizal (Redell,1991). Horii et al. (1974) have reported significant anti-pyretic activity of a medicine derived from the earthworms. Earthworms have been used for reducing fever due to its antipyretic activity and for testing pregnancy in human females (Hassenbein, 1951). They were also found useful for curing chronic cough, jaundice, diarrhoea and also for facilitating delivery (Wahid, 1961).

RECOMMENDATIONS

During recent years, the problem of efficient disposal and management of organic wastes has become more significant due to rapidly increasing population, intensive agriculture and industrialization in Nigeria. Production of large quantities of organic waste in Nigeria poses major environmental (offensive odours, contamination of ground water and soil) and disposal problems. Therefore, the disposal of different types of wastes has become very important issue for maintaining environmental health. Although various physical, chemical and microbiological methods of disposal of organic solid wastes are currently in use, these methods are time consuming but also involve high costs. Therefore, there is a pressing need to find out cost effective alternative methods of shorter duration particularly suited to Nigerian conditions. We therefore, recommend that vermicomposting as an "environmentally sustainable" economically viable" and socially acceptable" method for waste management in Nigeria.

It is well established that earthworms and vermicomposting have beneficial physical, biological and chemical effects on soils and many researchers have demonstrated that these effects can increase plant growth crop yields in both natural and managed ecosystems. In Nigeria, many of our agricultural farm lands have lost their fertility and nutrients over time due over used, leaching, bush burning and other factors. These have led to decreased in food productivity and a major problem for local farmers. These problems are further exacerbated by lack of affordable fertilizers, particularly for low income

farmers. Hence, we therefore recommend the use and application of earthworms and its vermicomposting technology in providing organically rich nutrients to our agricultural farm lands.

CONCLUSION

Earthworms as soil engineers play a key role in soil organic matter turnover, soil structure, mineralization of nutrients, heavy metals bioavailability, and land remediation. Recently the vermicomposting technology has proven an environmentally sustainable, economically viable and socially acceptable method for waste management and land remediation. Earthworm's vermicomposting has been shown to significantly improved plants growths and yields; however, there is still some gap. Very few papers talk about the negative role of earthworm in the soil ecosystem, hence further study is necessary to explore the negative effects of earthworms and their role in extreme conditions like permanent water stagnation. Further study, is also needed to identify and screens earthworms with strong resistance to heavy metals. In Nigeria, the use of earthworms and vermiposting is not widely practiced, hence we recommend that it should be use in land remediation and waste management in Nigeria.

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